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Biology and Ecology of the Threatened Inflated Heelsplitter Mussel, *Potamilus inflatus*, in the Black Warrior and Tombigbee Rivers, Alabama, June 1994

by Andrew C. Miller, David Armistead, Barry S. Payne

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Prepared for U.S. Army Engineer District, Mobile

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U.S. Army Corps of Engineers
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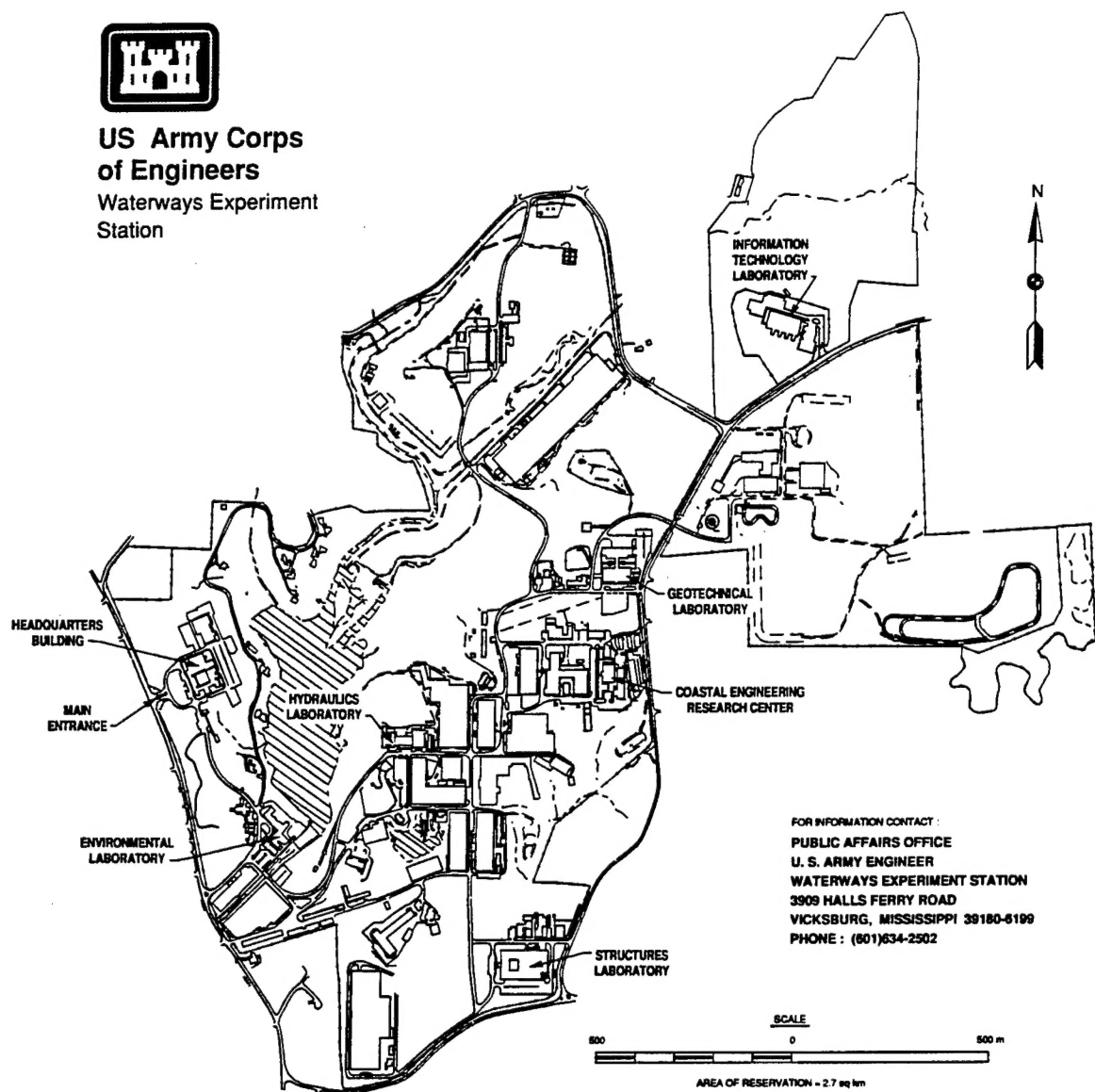
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Preface

A study of the inflated heelsplitter mussel, *Potamilus inflatus*, listed as threatened by the U.S. Department of Interior, was conducted on 6-10 July 1994 in selected reaches of the Black Warrior and Tombigbee rivers. The study was conducted by personnel of the U.S. Army Engineer Waterways Experiment Station (WES) in Vicksburg, MS, with divers from the Tennessee Valley Authority (TVA). Work was funded by the U.S. Army Engineer District, Mobile. Personnel of WES had a collecting permit from the State of Alabama and an endangered species collecting permit from Region IV, U.S. Fish and Wildlife Service, Atlanta, GA. No *P. inflatus* were sacrificed, although a few individuals of common species were placed in the reference collection at WES. The purpose was to obtain detailed information on the biology and ecology of the inflated heelsplitter mussel. This information will be used to evaluate effects of dredging on this species.

Divers were Messrs. Larry Neill, Robert T. James, Jeff Montgomery, and Kevin Chalk. Assistance in the field was provided by Mr. David Armistead, Millsaps College, and Adrian Hall, Alcorn University, contract students, WES. Mr. Doug Lee was the WES diving inspector. Ms. Geralline Wilkerson, Jackson State University, prepared tables. TVA personnel provided safety equipment, foul weather gear, and a global positioning system. This study was designed by Drs. Andrew C. Miller and Barry S. Payne, WES, with assistance by Messrs. Brian Peck, Frederick Horn, and Mark Goddard, Mobile District.

During the conduct of this study, Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Ecological Research Division (ERD), EL; and Dr. Alfred F. Cofrancesco was Chief, Aquatic Ecology Branch, ERD.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Introduction

Background

The U.S. Army Engineer District, Mobile, must dispose of dredged material at selected areas along the Black Warrior and Tombigbee (BWT) rivers, Alabama (U.S. Army Corps of Engineers 1987). Dredging is at a depth of 9 ft¹ plus 4 ft of overdredge and will maintain a 200-ft-wide channel. "Within Banks Disposal Areas" are used so that dredged material is placed along the shore or in shallow water within banks. Recently deposited material is subject to erosive action of high water.

Disposal areas are near sites where the inflated heelsplitter, *Potamilus inflatus*, has been collected (Stewart 1993). This species, listed as threatened by the U.S. Fish and Wildlife Service (FWS) in 1990, has also been found in the Amite River, Louisiana (FWS 1991). Stern (1976) reported that *P. inflatus* usually inhabits soft, stable substratum in slow to moderate current. Hartfield (1988a,b) reported that this species is found in sand, mud, and sandy gravel, but not in large gravel or armored gravel. *Potamilus inflatus* is similar to the pink heelsplitter, *Potamilus ohioensis*; however, the latter is less inflated and found in sloughs and lakes where inflated heelsplitters are not collected.

In May 1993, personnel of the U.S. Army Engineer Waterways Experiment Station (WES) conducted a survey of dredged material disposal areas in the BWT rivers (Miller 1994). Divers from the Tennessee Valley Authority were used to search specific disposal areas and retrieve mussels by hand. Twenty-eight disposal areas were surveyed requiring 26.8 hr of underwater searching. Thirty-three of the sixty-three live bivalves collected were *P. inflatus*. After this study was completed, the determination was made that additional studies on the biology and ecology of *P. inflatus* were required. This additional information will be used to evaluate the effects of dredging and disposal of dredged material on the inflated heelsplitter. The objectives of this second study, conducted in 1994, were as follows:

¹ A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

- a. Determine density, size, and age of *P. inflatus* inhabiting sandy areas along the shore, some affected and some unaffected by disposal of dredged material.
- b. Determine density, size, and age of *P. inflatus* at historically prominent, high-quality, stable gravel bars that have never been affected by dredging.
- c. Collect data on water depth, velocity, and substratum type where *P. inflatus* is found.
- d. Investigate the ability of *P. inflatus* to rebury after being dislodged from the substratum and to extricate itself after being buried in sand. This task was designed to mimic dredging impacts.

Purpose and Scope

The purpose was to obtain detailed information on the biology and ecology of *P. inflatus*. Study design was based upon information needs of Mobile District personnel. Data collected during this study will be used by District personnel to evaluate the effects of dredging and disposal of dredged material on *P. inflatus*.

2 Study Area and Methods

Study Area

The Black Warrior River originates north of Tuscaloosa in north-central Alabama and flows south to the Tombigbee River where it enters at River Mile (RM) 217 near Demopolis, AL (Figure 1). The original source of the Tombigbee River was in north-eastern Mississippi. It flowed south and east before entering Alabama just west of Tuscaloosa, AL. However, following completion of the Tennessee-Tombigbee Waterway in the 1980s, the Tombigbee River now connects with the Tennessee River in northwestern Alabama. After being joined by the Black Warrior River, the Tombigbee River flows south toward Mobile, AL. The Alabama River enters the Tombigbee River at RM 46.6, and the two rivers become the Mobile River.

Semiquantitative methods were used to collect mussels at seven locations on the BWT rivers on 6 and 7 July 1994 (Table 1, Figure 2). Study areas included an embayment first surveyed by FWS personnel and never affected by dredging (RM 327.2); four areas where dredging and disposal took place in 1993 (12 Mile Rock, 323 Bar, Hulls Bar, and McGowin Bluff); and two areas similar to the previous four that have never been affected by dredging or disposal (at RM 320.9 between Highway 42 Bridge and I-59 Bridge) and between RMs 303.3 and 302.8 immediately downriver of Moundville, AL. The embayment surveyed by FWS personnel had reduced velocity, and substratum consisted mainly of silt, mud, and detritus. Therefore, results from this latter site are not comparable with information collected at other sites along the river.

Quantitative mussel samples were also obtained at stable sand/gravel bars located immediately downriver of Selden Lock and Dam (RM 261.5) and Demopolis Lock and Dam (RM 211.9) (Table 1). Flood elevations between RMs 0 and 350, which include areas surveyed, are depicted in Figure 3; the actual slope (number of feet per linear mile) is in Table 2.

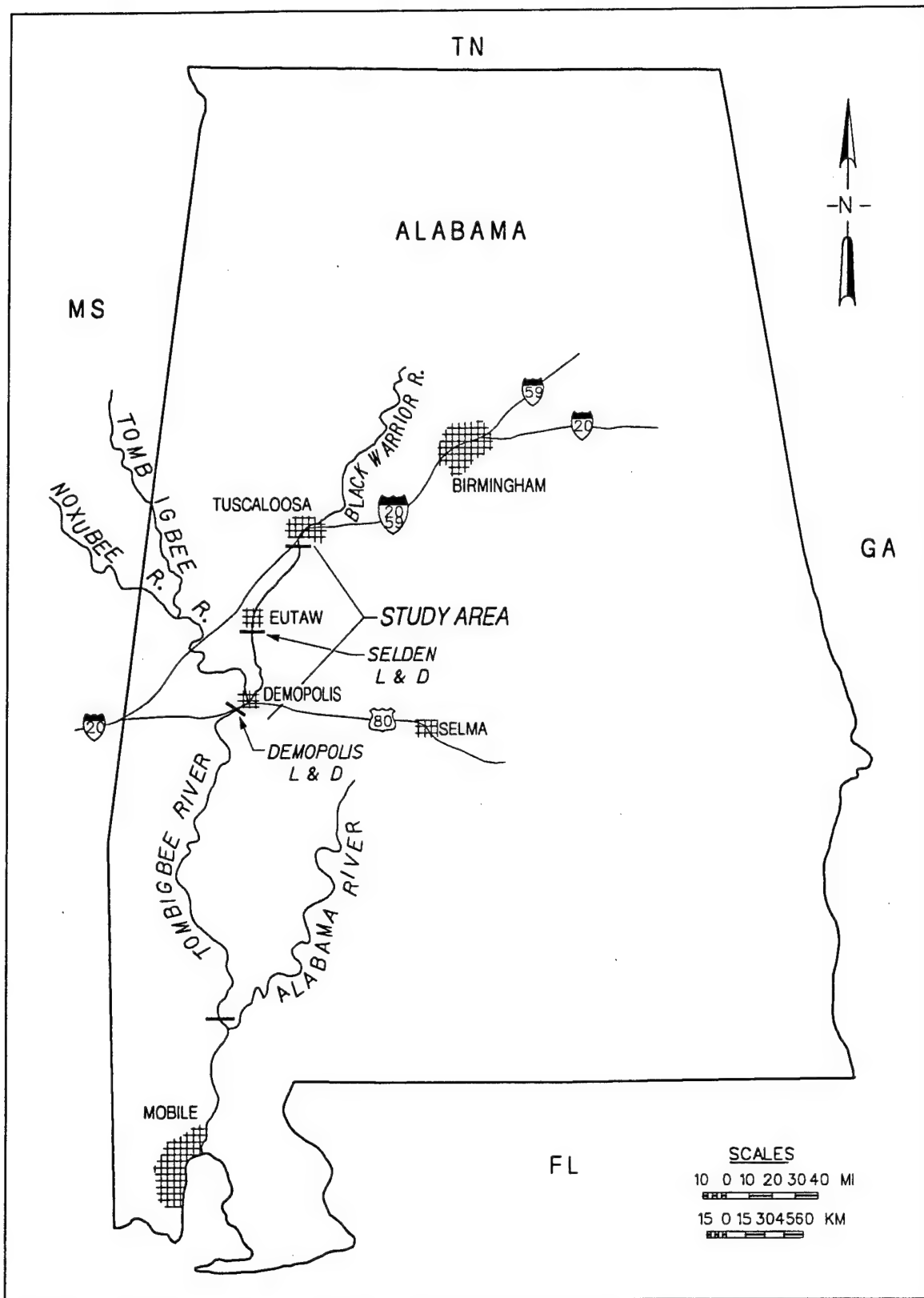


Figure 1. Map of study area

Table 1
River Miles Surveyed, Dates, and Summary of Tasks Completed
for the 1994 BWT Rivers Survey

Date	Dive Number	River Mile	Site Description	Tasks
7 Jul	24, 25	327.2	High-density site reported by USFWS, never dredged	Qualitative mussel collections
7 Jul	20-23	326.9	12 Mile Rock, dredged in 1993	Qualitative mussel collections; water velocity studies
7 Jul	16-19	322.6-322.0	323 Bar, dredged in 1993	Qualitative mussel collections
7 Jul	13-15	320.9	Between Highway 42 and I-59 bridge, never dredged	Qualitative mussel collections
6 Jul	7-10	309.4-308.9	Hulls Bar, dredged in 1993	Qualitative mussel collections
6 Jul	5, 6 and 11, 12	304.1-303.8	McGowin Bluff, dredged in 1993	Qualitative mussel collections
6 Jul	1-4	303.3-302.8	Immediately downriver of Moundville, never dredged	Qualitative mussel collections; water velocity studies
8 Jul		261.5	Immediately downriver of Selden Lock and Dam	Qualitative mussel collections
9-10 Jul		211.9	Immediately downriver of Demopolis Lock and Dam	Qualitative mussel collections
Note: Many dives were completed on 8-10 July; so no specific dive numbers were assigned.				

Methods

Mussel collection methods

All underwater work was accomplished by a five-person dive crew with surface-supplied air and communication equipment. Qualitative collections were made by having two divers work simultaneously along transects perpendicular to shore. Each diver entered the water near the channel, worked toward shore, moved upriver, then worked out toward the channel again. The total search time underwater was recorded. The estimation was made that divers covered approximately 5 m² of river bottom per minute. Density was estimated as the number of individuals collected per area (usually numbers/100 m²) and time (mussels collected per minute of search time). The number

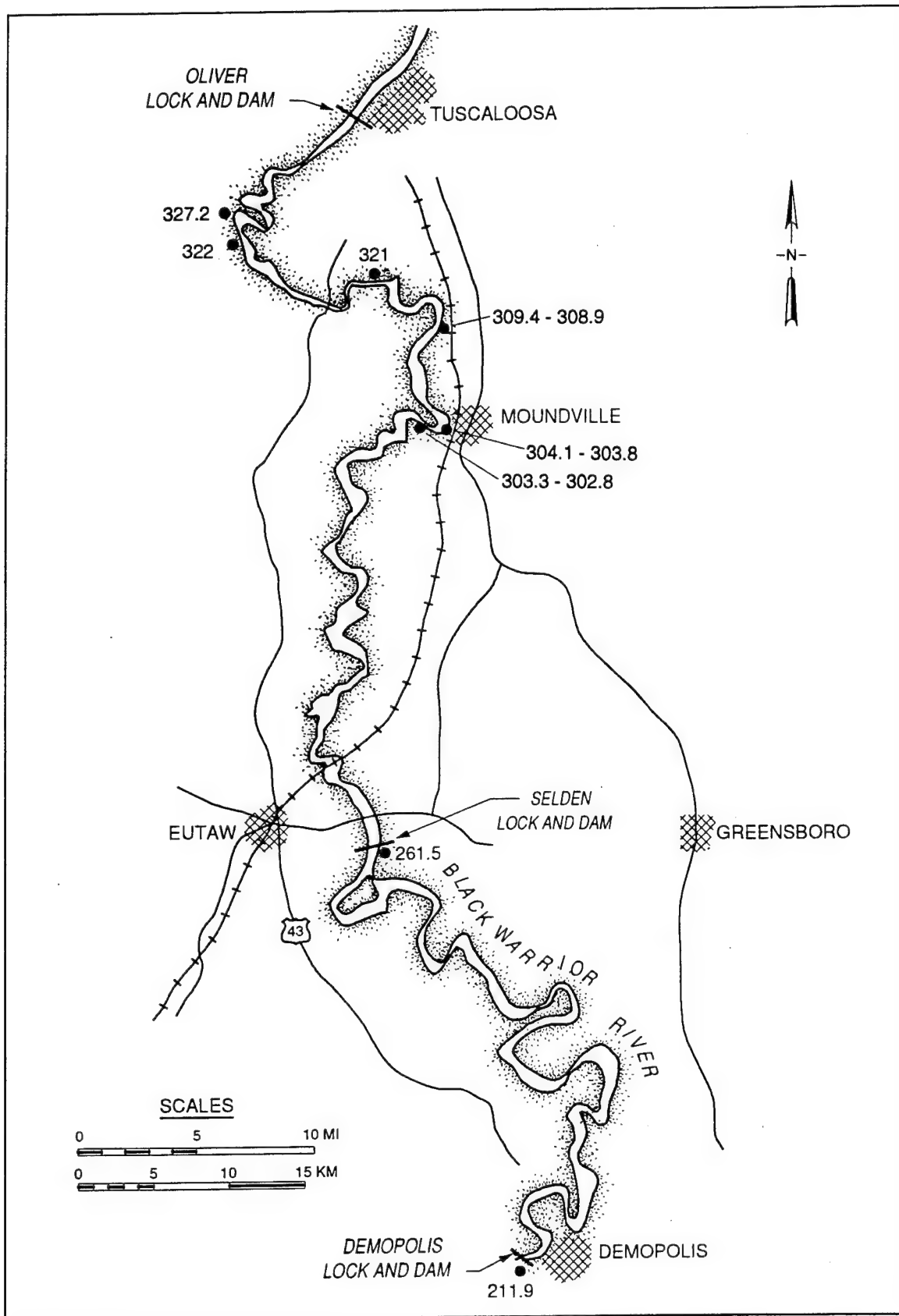


Figure 2. Location of study sites for 1994 survey

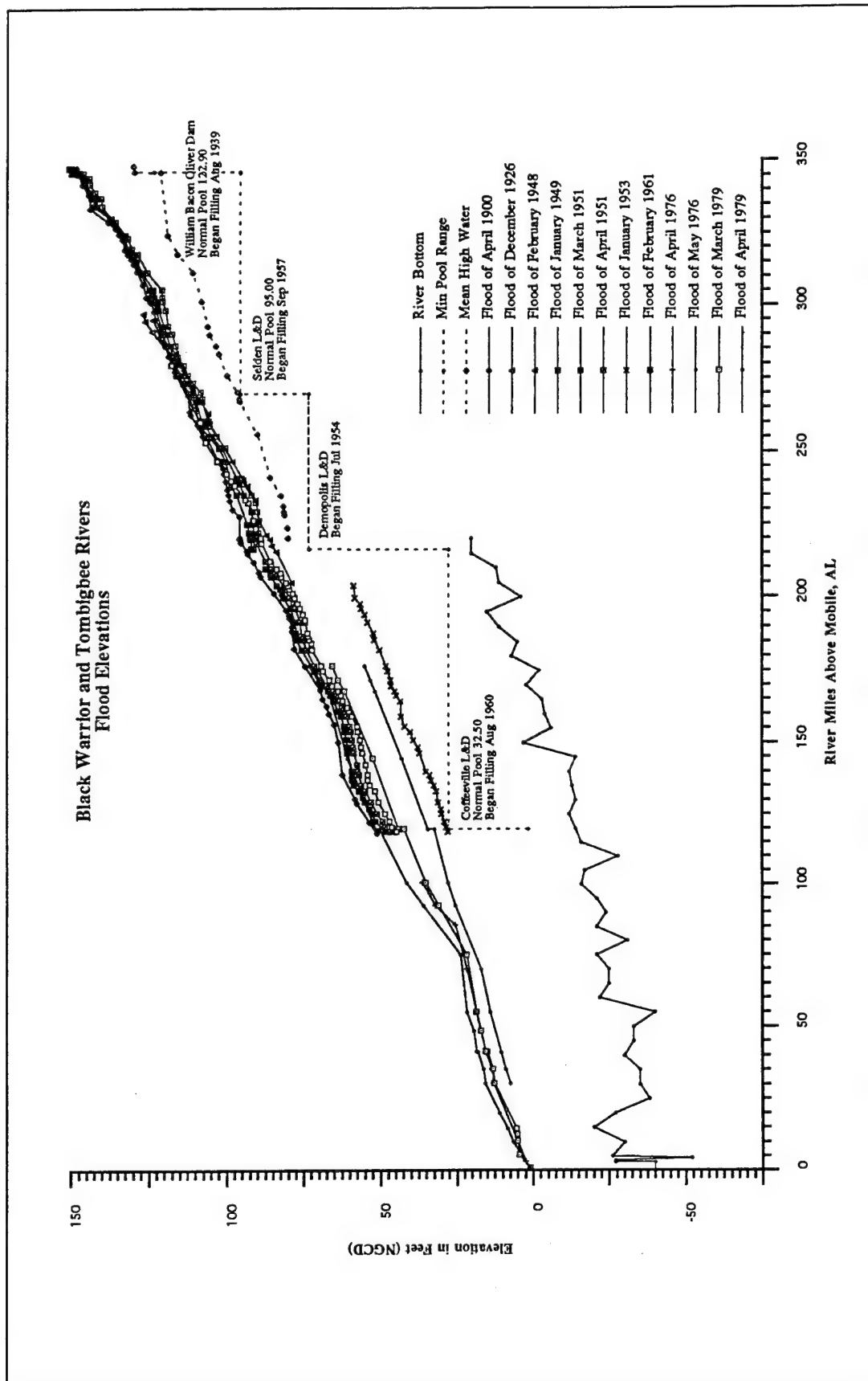


Figure 3. Elevation in feet versus river mile for selected flood elevations in the BWT rivers

Table 2
Slope in Bed Elevation for the BWT Rivers in 1-Mile Increments

RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile
1-2	0.7	76-77	0.7	151-152	0.3	226-227	0.0	301-302	0.7
2-3	0.4	77-78	0.8	152-153	0.2	227-228	0.4	302-303	0.7
3-4	0.4	78-79	0.6	153-154	0.3	228-229	0.8	303-304	0.2
4-5	0.5	79-80	0.7	154-155	0.3	229-230	0.8	304-305	0.3
5-6	0.5	80-81	0.7	155-156	0.2	230-231	0.4	305-306	0.3
6-7	0.4	81-82	0.8	156-157	0.3	231-232	0.3	306-307	0.2
7-8	0.4	82-83	0.7	157-158	0.3	232-233	0.2	307-308	0.4
8-9	0.5	83-84	0.6	158-159	0.2	233-234	0.2	308-309	0.5
9-10	0.4	84-85	0.7	159-160	0.3	234-235	0.2	309-310	0.4
10-11	0.4	85-86	0.6	160-161	0.2	235-236	0.2	310-311	0.5
11-12	0.4	86-87	0.8	161-162	0.3	236-237	0.3	311-312	0.5
12-13	0.4	87-88	0.7	162-163	0.3	237-238	0.2	312-313	0.3
13-14	0.3	88-89	0.7	163-164	0.2	238-239	0.4	313-314	0.2
14-15	0.6	89-90	0.7	164-165	0.3	239-240	0.1	314-315	0.5
15-16	0.4	90-91	0.7	165-166	0.3	240-241	0.2	315-316	0.5
16-17	0.5	91-92	0.7	166-167	0.2	241-242	0.1	316-317	0.7
17-18	0.5	92-93	0.7	167-168	0.4	242-243	0.2	317-318	0.7
18-19	0.3	93-94	0.7	168-169	1.0	243-244	0.1	318-319	0.6
19-20	0.7	94-95	0.6	169-170	0.8	244-245	0.3	319-320	0.3
20-21	0.5	95-96	0.8	170-171	0.8	245-246	0.1	320-321	0.2
21-22	0.4	96-97	0.6	171-172	0.7	246-247	0.2	321-322	0.1
22-23	0.5	97-98	0.8	172-173	0.7	247-248	1.0	322-323	0.4
23-24	0.4	98-99	0.7	173-174	0.5	248-249	0.6	323-324	0.6
24-25	0.5	99-100	0.6	174-175	0.5	249-250	0.5	324-325	0.7
25-26	0.4	100-101	0.7	175-176	0.6	250-251	0.5	325-326	0.5
26-27	0.6	101-102	0.5	176-177	0.6	251-252	0.6	326-327	0.7
27-28	0.3	102-103	0.4	177-178	0.6	252-253	0.5	327-328	0.9
28-29	0.6	103-104	0.4	178-179	0.6	253-254	0.5	328-329	1.1
29-30	0.4	104-105	0.5	179-180	0.6	254-255	1.2	329-330	1.1
30-31	0.4	105-106	0.5	180-181	0.6	255-256	0.8	330-331	1.2

(Sheet 1 of 3)

Note: Slopes for RM 1-176 were calculated from flood of April 1979 elevations. Slopes for RM 177-348 were calculated from flood of April 1900 elevations.

Table 2 (Continued)									
RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile
31-32	0.0	106-107	0.4	181-182	0.6	256-257	0.5	331-332	1.2
32-33	0.1	107-108	0.7	182-183	0.2	257-258	0.4	332-333	1.1
33-34	0.0	108-109	0.3	183-184	0.1	258-259	0.6	333-334	1.0
34-35	0.1	109-110	0.4	184-185	0.1	259-260	0.5	334-335	0.2
35-36	0.4	110-111	0.5	185-186	0.2	260-261	0.6	335-336	0.1
36-37	0.3	111-112	0.4	186-187	0.1	261-262	0.6	336-337	0.2
37-38	0.3	112-113	0.6	187-188	0.1	262-263	0.3	337-338	0.2
38-39	0.3	113-114	0.4	188-189	0.1	263-264	0.3	338-339	0.2
39-40	0.3	114-115	0.4	189-190	0.1	264-265	0.2	339-340	0.5
40-41	0.3	115-116	0.5	190-191	0.2	265-266	0.1	340-341	0.6
41-42	0.5	116-117	0.4	191-192	0.2	266-267	0.1	341-342	0.6
42-43	0.1	117-118	0.5	192-193	0.3	267-268	0.1	342-343	0.2
43-44	0.2	118-119	0.5	193-194	0.4	268-269	0.2	343-344	0.1
44-45	0.1	119-120	1.6	194-195	0.4	269-270	0.1	344-345	1.0
45-46	0.1	120-121	0.4	195-196	0.6	270-271	0.3	345-346	2.3
46-47	0.2	121-122	0.3	196-197	0.8	271-272	0.6	346-347	2.0
47-48	0.1	122-123	0.4	197-198	0.7	272-273	0.5	347-348	1.7
48-49	0.2	123-124	0.3	198-199	0.8	273-274	0.5		
49-50	0.4	124-125	0.4	199-200	0.6	274-275	0.8		
50-51	0.2	125-126	0.4	200-201	0.7	275-276	0.9		
51-52	0.5	126-127	0.4	201-202	0.7	276-277	0.3		
52-53	0.3	127-128	0.4	202-203	0.8	277-278	0.3		
53-54	0.4	128-129	0.3	203-204	0.8	278-279	0.2		
54-55	0.3	129-130	0.4	204-205	0.8	279-280	0.3		
55-56	0.1	130-131	0.3	205-206	0.7	280-281	0.2		
56-57	0.1	131-132	0.4	206-207	0.7	281-282	0.6		
57-58	0.1	132-133	0.5	207-208	0.3	282-283	0.4		
58-59	0.1	133-134	0.3	208-209	0.5	283-284	0.5		
59-60	0.1	134-135	0.4	209-210	0.5	284-285	0.4		
60-61	0.1	135-136	0.4	210-211	0.4	285-286	0.3		
61-62	0.1	136-137	0.3	211-212	0.5	286-287	0.2		
62-63	0.1	137-138	0.4	212-213	0.7	287-288	0.2		
63-64	0.1	138-139	0.4	213-214	0.7	288-289	0.4		
(Sheet 2 of 3)									

Table 2 (Concluded)									
RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile	RM	ft/mile
64-65	0.1	139-140	0.3	214-215	0.6	289-290	0.1		
65-66	0.1	140-141	0.4	215-216	0.5	290-291	0.4		
66-67	0.2	141-142	0.4	216-217	0.6	291-292	0.4		
67-68	0.0	142-143	0.4	217-218	0.6	292-293	0.4		
68-69	0.1	143-144	0.3	218-219	0.5	293-294	0.7		
69-70	0.1	144-145	0.3	219-220	0.1	294-295	0.4		
70-71	0.1	145-146	0.3	220-221	0.0	295-296	0.1		
71-72	0.1	146-147	0.3	221-222	0.1	296-297	0.1		
72-73	0.1	147-148	0.3	222-223	0.0	297-298	0.1		
73-74	0.1	148-149	0.2	223-224	0.1	298-299	0.3		
74-75	0.1	149-150	0.2	224-225	0.0	299-300	0.5		
75-76	0.6	150-151	0.3	225-226	0.1	300-301	0.3		
(Sheet 3 of 3)									

of mussels obtained per minute was multiplied by 20 to obtain an estimate of the number of mussels collected per 100 m².

Total shell length (SL) and inflation (maximum width of each individual) of each *P. inflatus* were recorded. All *P. inflatus* were held in 20-ℓ buckets during the survey, then replaced in the substratum near RM 320.9 where dredging has never taken place.

Quantitative collections were made by having two divers remove all substratum within a 0.25-m² aluminum quadrat. At each location, 10 quadrats were collected at each of four subsites. Therefore, a total of 80 quantitative samples were collected, 40 from a site immediately downriver of Selden Lock and Dam and 40 from immediately downriver of Demopolis Lock and Dam.

All mussels were brought to the surface, identified, and total SL measured with calipers. Selected specimens of species not protected under the Endangered Species Act of 1973 were returned to WES and catalogued in the reference collection. If time permitted, mussels were identified and measured in the field; otherwise, they were preserved in 10-percent buffered formalin and processed in the laboratory.

Methods for sampling mussels were based on techniques described in Miller and Nelson (1983); Isom and Gooch (1986); Kovalak, Dennis, and Bates (1986); Miller and Payne (1988); and Miller et al. (1994). Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962), Parmalee (1967), Starrett (1971), and Burch (1975).

Mr. Paul Hartfield, FWS, Jackson, MS, verified species and provided a reference specimen of *P. inflatus* to take into the field. Nomenclature is consistent with Turgeon et al. (1988).

All calculations were done with programs written in SAS (Statistical Analytical System) on a personal computer. Discussion of statistical procedures that were used can be found in Green (1979) and Hurlbert (1984). Species area curves were constructed from qualitative data.

Water velocity measurements

The sensor for a Marsh McBirney Model 527 water velocity meter was placed about 10 cm above the mussel bed along the left descending bank (LDB) at RM 287. Data on ambient water velocity were collected at three times during the day. The instrument was coupled to a data logger so velocity could be collected for several minutes and recorded at 1-sec intervals. The sensor collects data parallel to and at right angles to flow; these two readings are used to calculate net or combined flow as well as direction of flow (measured in degrees). Maximum, minimum, mean, and standard deviation (an estimate of turbulence or variation about mean values) were then calculated.

3 Results

Substratum Characteristics

Disposal and nondisposal areas along the BWT rivers

Substratum along the BWT rivers where *P. inflatus* were collected consisted mainly of fine sand (0.075 to 0.424 mm) and silt (<0.075 mm), which together comprised approximately 90 percent of each sample (Figure 4). Substratum characteristics at areas where material was disposed in 1993 differed little from those unaffected by disposal. Substratum at areas unaffected by disposal had about 10 percent more silt and a slightly higher overall percentage of fine sand (0.075 to 0.424 mm) than at unaffected areas. Overall differences in substratum composition between areas recently affected and unaffected by

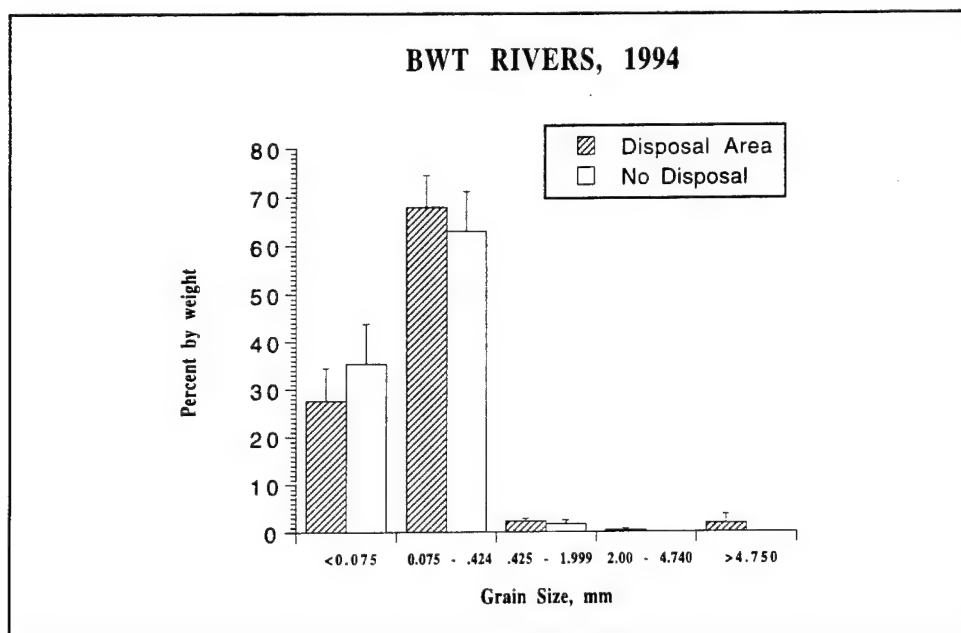


Figure 4. Grain-size distribution at collection sites in the BWT rivers affected and unaffected by recent disposal of dredged material

disposal were minor and probably had no affect on density or distribution of *P. inflatus*. Data on grain-size distribution in samples collected from areas affected and unaffected by disposal of dredged material appear in Table A1, Appendix A.

Gravel bars

Particles less than 6.35 mm in diameter comprised less than 50 percent of the substratum at sites immediately downriver of the two locks and dams (Figures 5 and 6). Intermediately sized particles (between 6.35 and 12.7 mm and between 12.7 and 34.0 mm) made up 20 to 40 percent of the samples. Larger sized particles, gravel greater than 34.0 mm in diameter, comprised about 5 percent of each sample. These data should be compared with grain-size distribution of sediments along the shore where *P. inflatus* was collected. Regardless of the effects of disposal, grain sizes greater than 4.7 mm comprised less than 5 percent of the sample from the gravel bars (compare Figure 4 with Figures 5 and 6).

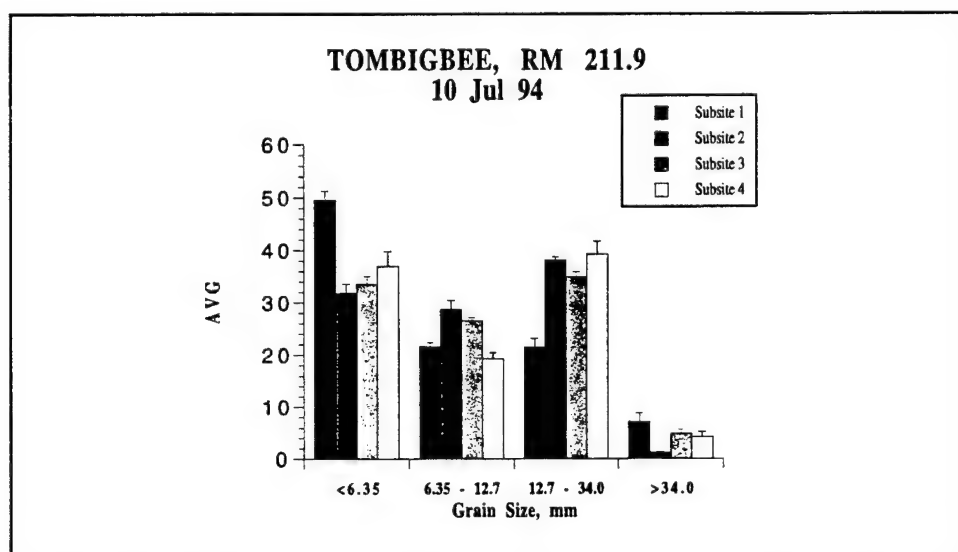


Figure 5. Grain-size distribution at four subsites immediately downriver of Demopolis Lock and Dam (RM 211.9)

Water Velocity

Continuous measures of water velocity were made at two locations in the Black Warrior River, at RM 326.9 (affected by dredging and disposal in 1993), and near RM 303.3 (never affected by dredging or dredged material disposal). Summary statistics and plots of selected trials are in Appendix B. Water velocity at locations where *P. inflatus* was collected was moderate; all values were less than 1.5 ft/sec. Minimum and maximum values for net (combined)

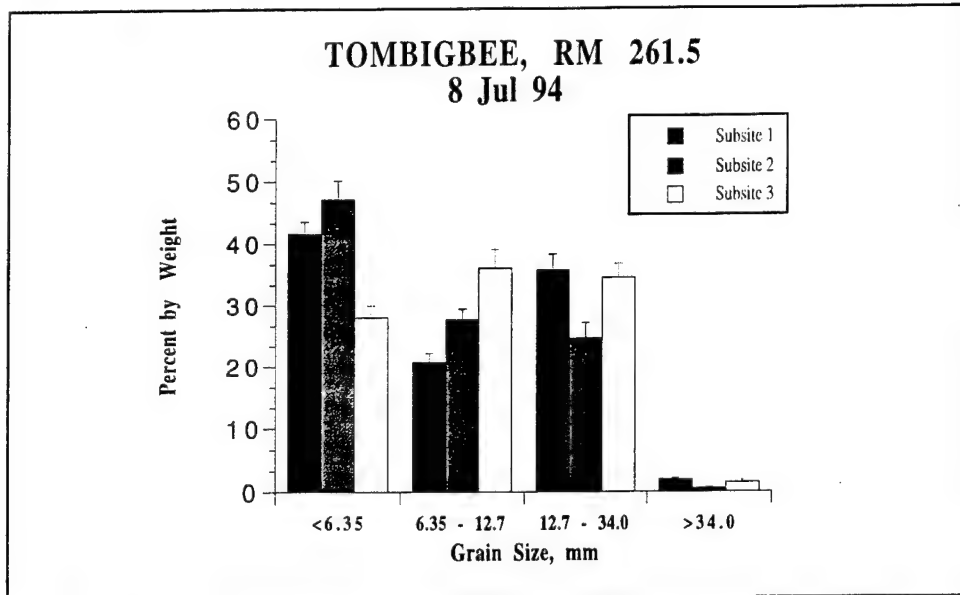


Figure 6. Grain-size distribution at three subsites immediately downriver of Selden Lock and Dam (RM 261.5)

water velocity at RM 309.2 were 0.752 and 1.023 ft/sec with a range of only 0.271 (Table B1, Appendix B).

Data collected at 1-sec intervals depict conditions where velocity is either gradually increasing or decreasing over a short period of time. These gradual changes are subtle and usually consist of only a few tenths of a foot/second. Long-term measures of velocity (over several hours) would reveal a cycle of gradual increases and decreases.

Water velocity measured at sites where *P. inflatus* was collected is less than that required to erode medium- to fine-grained sand. During periods of low water in the spring and summer when *P. inflatus* is respiring and feeding, values less than 1.5 ft/sec would not be disruptive. High-velocity water, greater than 2.0 ft/sec during high flow, would likely move substratum and large and small specimens of *P. inflatus*. However, as will be shown below, this species has the ability to quickly rebury after being extricated from the substratum.

Bivalve Community

Bivalve community at gravel bars

Thirteen and eight species, respectively, of bivalves were collected immediately downriver of Demopolis Lock and Dam and Selden Lock and Dam using qualitative methods (Table 3). At both locations, the fauna was dominated by

Table 3
Percent Abundance (Abun) and Frequency of Occurrence
(Occur) of Freshwater Mussel Data Collected Using Qualitative
Methods Immediately Downriver of Demopolis Lock and Dam
(RM 211.9) and Selden Lock and Dam (RM 261.5), July 1994

Species	Demopolis Lock and Dam		Selden Lock and Dam	
	Abun	Occur	Abun	Occur
<i>Fusconaia ebena</i> (I. Lea, 1831)	56.28	100.00	40.00	100.00
<i>Obliquaria reflexa</i> Rafinesque, 1820	18.76	83.33	0.00	0.00
<i>Quadrula asperata</i> (I. Lea, 1861)	13.74	86.11	2.22	50.00
<i>Quadrula rumphiana</i> (I. Lea, 1852)	3.52	44.44	2.22	50.00
<i>Ellipsaria lineolata</i> (Rafinesque, 1820)	1.68	25.00	2.22	50.00
<i>Megaloniais nervosa</i> (Rafinesque, 1820)	1.51	19.44	0.00	0.00
<i>Plectomerus dombeyanus</i> (Valenciennes, 1827)	1.17	16.67	2.22	50.00
<i>Potamilus inflatus</i> (I. Lea, 1831)	1.17	19.44	2.22	50.00
<i>Fusconaia flava</i> (Rafinesque, 1820)	0.67	11.11	0.00	0.00
<i>Potamilus alatus</i> (Say, 1817)	0.67	2.78	0.00	0.00
<i>Leptodea fragilis</i> (Rafinesque, 1820)	0.34	5.56	0.00	0.00
<i>Potamilus purpuratus</i> (Lamarck, 1819)	0.34	5.56	0.00	0.00
<i>Corbicula fluminea</i> (Muller, 1774)	0.17	2.78	0.00	0.00
<i>Obovaria olivaria</i> (Rafinesque, 1820)	0.00	0.00	2.22	50.00
<i>Pleurobema pyramidatum</i> (I. Lea, 1840)	0.00	0.00	2.22	50.00
Total individuals	597		45	
Total species	13		8	
Total samples		36		2

Fusconaia ebena, two species of *Quadrula*, and *Obliquaria reflexa*, which are all thick-shelled organisms common in sand-gravel substratum. *Potamilus inflatus* was uncommon and represented 1.17 and 2.2 percent of the fauna at these two gravel bars. The nonindigenous *C. fluminea* was less than 1 percent of the fauna. No zebra mussels, *Dreissena polymorpha*, were found.

Thick-shelled species also dominated the fauna collected with quantitative methods at both locations (Tables 4 and 5). *Potamilus inflatus* was found downriver of Demopolis Lock and Dam but not immediately downriver of Selden Lock and Dam. There was moderate evidence of recent recruitment at both locations; between 5 and 10 percent of all individuals were less than 30-mm total SL. Thirty-five percent of the species downriver of Demopolis

Table 4
Percent Abundance (Abun) and Occurrence (Occur) and Summary Statistics for Freshwater Bivalves Collected at a Gravel Bar Immediately Downriver of Demopolis Lock and Dam (RM 211.9), July 1994

Species	Abun	Occur
<i>F. ebena</i>	43.56	75.0
<i>O. reflexa</i>	20.44	47.5
<i>Q. asperata</i>	18.23	47.5
<i>E. lineolata</i>	2.76	10.0
<i>F. flava</i>	2.76	10.0
<i>Q. rumphiana</i>	3.31	15.0
<i>P. dombeyanus</i>	2.21	10.0
<i>P. inflatus</i>	1.66	7.5
<i>C. fluminea</i>	1.66	7.5
<i>M. nervosa</i>	1.10	5.0
<i>Elliptio crassidens</i> (Lamarck, 1819)	1.10	5.0
<i>Truncilla donaciformis</i> (l. Lea, 1828)	0.55	2.5
<i>Amblema p. plicata</i> (Say, 1817)	0.55	2.5
Total individuals	181	
Total species	13	
Total samples	40	
Total sites	4	
% Individuals <30 mm	9.4	
% Species <30 mm	35.7	
Species diversity (H')	1.68	
Evenness	0.63	
Menhenik's Index	0.97	

Lock and Dam and seventy-one percent of the species downriver of Selden Lock and Dam had at least one individual less than 30-mm total SL.

Bivalve community in sand/silt substratum along shore

Dredged material disposal areas along the BWT rivers are dominated by *P. inflatus*. In the 1993 survey, a total of 63 bivalves were collected at 69 sites located on 28 disposal areas (Miller 1994). Fifty-seven percent of the

Table 5
Percent Abundance (Abun) and Occurrence (Occur) and Summary Statistics for Freshwater Bivalves Collected at a Gravel Bar Immediately Downriver of Selden Lock and Dam (RM 261.5), July 1994

Species	Abun	Occur
<i>F. ebena</i>	32.95	42.5
<i>O. reflexa</i>	32.95	37.5
<i>Q. asperata</i>	23.86	42.5
<i>Q. rumphiana</i>	6.82	12.5
<i>M. nervosa</i>	1.14	2.5
<i>L. fragilis</i>	1.14	2.5
<i>Truncilla truncata</i> Rafinesque 1820	1.14	2.5
Total individuals	88	
Total species	7	
Total samples	40	
Total sites	4	
% Individuals <30 mm	7.9	
% Species <30 mm	71.4	
Species diversity (H')	1.41	
Evenness	0.87	
Menhenik's Index	0.75	

fauna, 36 out of 63 individuals, were *P. inflatus* (Figure 7). Twelve percent were thick-shelled species (*Quadrula* spp), thin- and moderately thick-shelled species comprised 20 percent, and the nonindigenous *Corbicula fluminea* comprised 12 percent of the fauna. At six locations sampled in 1994 with qualitative methods, *P. inflatus* dominated. The exception was a sample area at RM 327.2 (Table 1), first sampled by the FWS. The site was dissimilar from the other six disposal areas surveyed. It was a small, slack water embayment, and substratum consisted of gravel, sand, silt, and organic material. At this location, a total of 36 individuals were collected; *P. inflatus* comprised 5.6 percent of the fauna. The rest of the fauna consisted of thick- (86 percent) and thin-shelled (8.3 percent) species. The fauna of the embayment was more similar to that at stable sand and gravel bars located immediately downriver of Selden Lock and Dam and Demopolis Lock and Dam.

As discussed above, disposal of dredged material has little affect on substratum characteristics along the BWT rivers (Figure 4). However, percentage of small-sized particles along the shore of the BWT rivers differed markedly

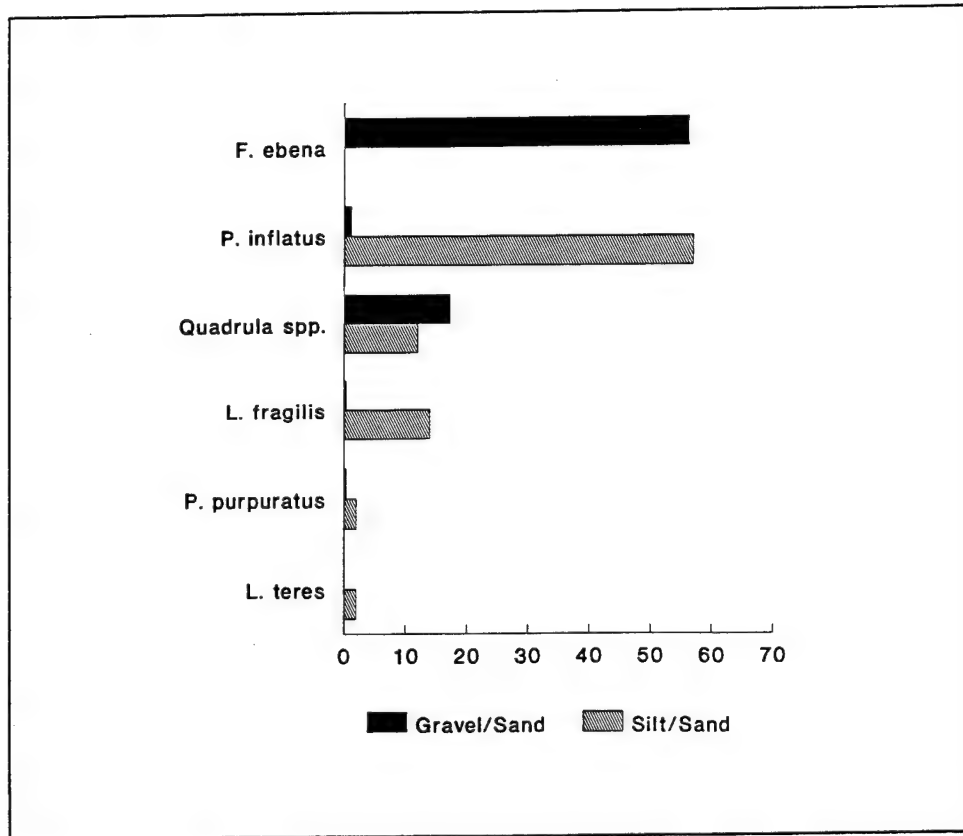


Figure 7. Habitat preferences for six species of Unionidae from gravel/sand and silt/sand substratum, BWT rivers, 1994

from that at gravel bars immediately downriver of Demopolis and Selden Lock and Dam (Figure 8). Particles less than 6.34 mm at the gravel bars comprised approximately 40 percent (as compared with nearly 100 percent along most of the shore) of each sediment sample.

Density

In the 1993 survey of disposal areas, density of *P. inflatus* ranged from 0.104 to 4.817 individuals/100 m² (Miller 1994). In the present (1994) survey, density of *P. inflatus* averaged 0.5 individuals/100 m² at disposal areas used in 1993 (maximum value = 1.34 individuals/100 m²) and 0.97 individuals/100 sq m (maximum value = 2.0 individuals/100 m²) at areas along the shore that had never been affected by disposal of dredged material.

Mean density of *P. inflatus* at the gravel bar immediately downriver of Demopolis Lock and Dam 0.3 ± 0.17 individuals/m² (or 30.0 ± 17 individuals/100 m²) was substantially greater than density in fine-grained sediments unaffected by dredged material disposal ($0.97, \pm 0.29$ individuals/100²), or in disposal areas ($0.5, \pm 0.15$ individuals/100²) (Figure 9). Collection rate

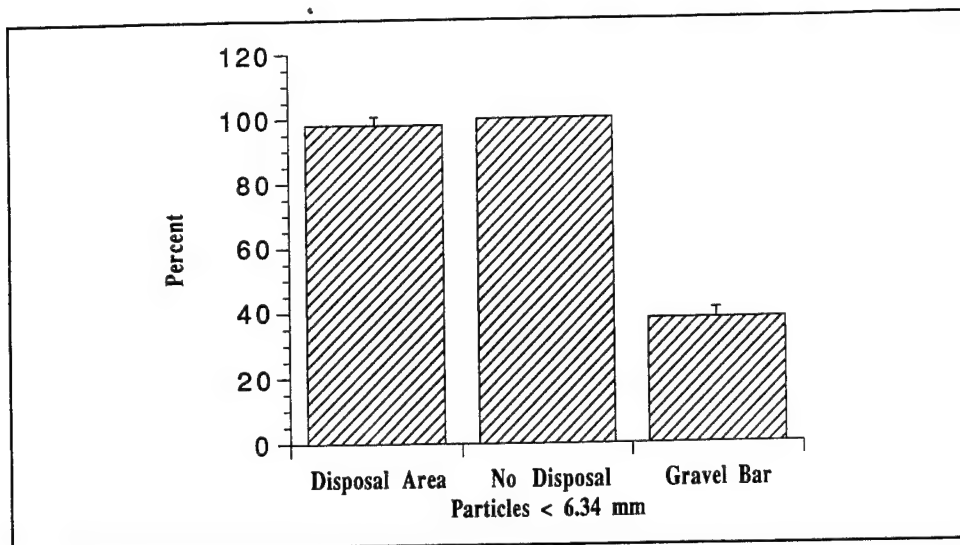


Figure 8. Percent abundance of *P. inflatus* at three habitat types in BWT rivers

(number/minute) and density (number/100 m²) for all study areas (both affected and unaffected by dredged material disposal) appear in Table A2, Appendix A). Because densities were so low, data were reported as numbers per 100 m².

Mean total unionid density immediately downriver of Demopolis Lock and Dam was 18.1 individuals/m², which was approximately double and

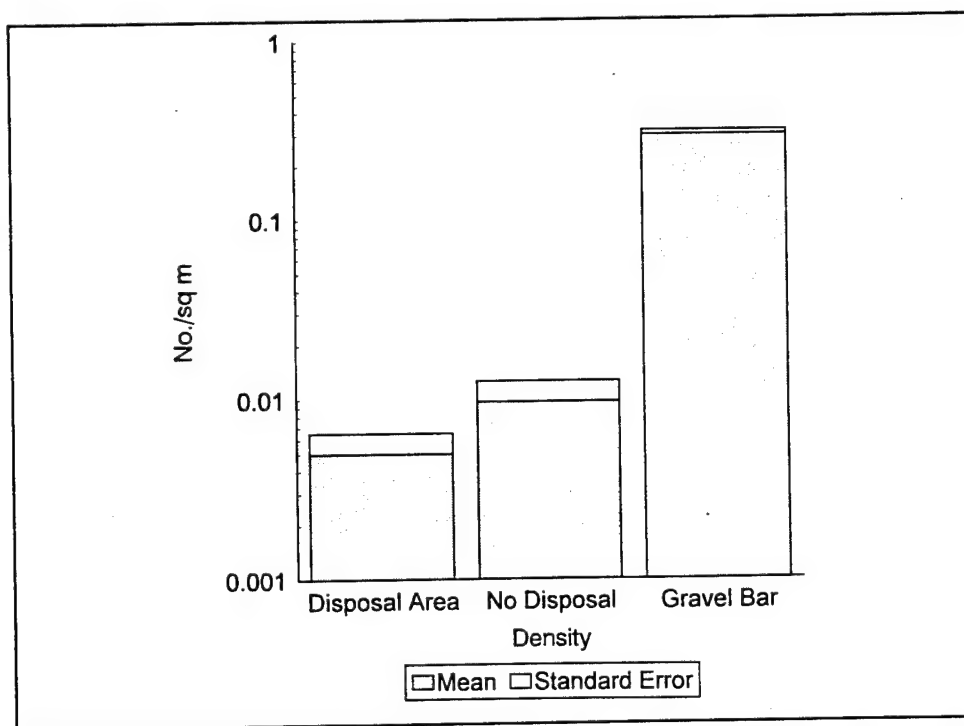


Figure 9. Density of *P. inflatus* at three habitat types along the BWT rivers

significantly ($p < 0.05$) greater than mean density immediately downriver of Selden Lock and Dam (8.8 individuals/m², Table 6, Figure 10). Although mean density values are low compared with those often found in other medium-sized rivers (50 to 100 individuals/m²), they are three to four orders of magnitude greater than mean density values in sand/silt substratum.

Table 6
Mean Density (individuals/square meter), Standard Error of the Mean (SE), F, and Probability Values (PR) for Quantitative Samples Collected at Two Locations Along the BWT Rivers, 1994

Subsite	N	Ave	SE	F	PR > F
Downriver of Demopolis Lock and Dam					
1	10	35.2 ^a	5.5		
2	10	9.6 ^c	2.7		
3	10	21.6 ^b	3.5		
4	10	6.0 ^c	1.2	13.59	0.0001
Total Density	40	18.1 ^A	2.5		
Downriver of Selden Lock and Dam					
1	10	5.6 ^a	1.5		
2	10	10.0 ^a	2.3		
3	10	10.4 ^a	2.2		
4	10	9.2 ^a	2.9	0.94	0.4334
Total Density	40	8.8 ^B	1.1	11.39	0.0012
Note: Means with the same superscript are not significantly different at the 0.05 Level. Duncan's Test was used to test for differences among subsites at a location (lower case subscript) and between locations (capital superscript). F = significance value from Duncan's multiple test.					

Size demography of *P. inflatus*

The minimum and maximum SL of *P. inflatus* was virtually identical in 1993 and 1994 (Figure 11). In 1993, individuals ranged from 32 to 138 mm long. In 1994, individuals ranged from 30 to 140 mm. Evidence of strong recruitment was apparent in both years. Approximately 25 percent of the population was less than 60 mm long in 1993, and approximately 33 percent of the population was less than 42 mm long in 1994. The mussels ranging from 30 to 42 mm long in 1994 probably represent the 1993 year class.

As its specific name implies, the inflation of a single shell of *P. inflatus* is comparatively greater than inflation of two other closely related species of *Potamilus* (Figure 12). Inflation was measured as the distance in millimeters

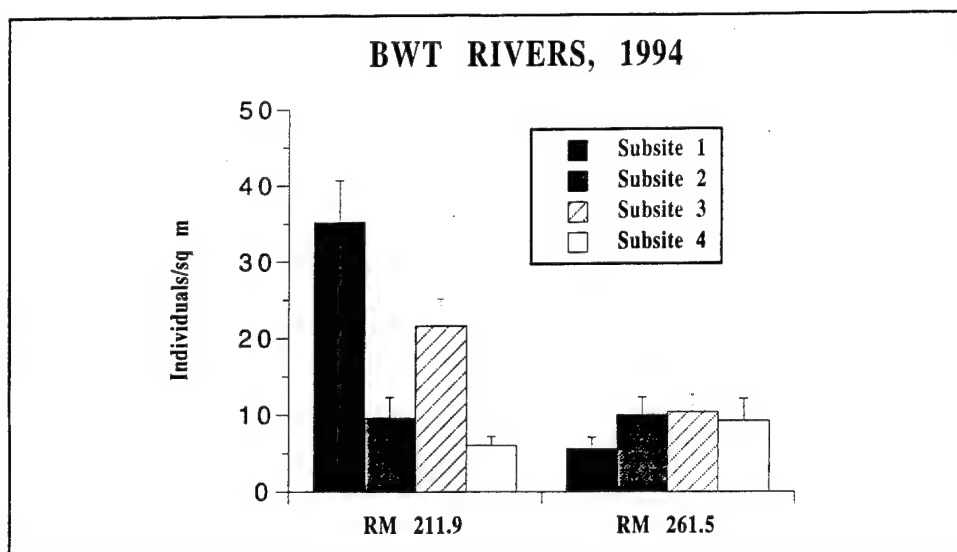


Figure 10. Total bivalve density at subsites immediately downriver of Demopolis Lock and Dam (RM 211.9) and Selden Lock and Dam (RM 261.5)

from a flat surface that a single shell is lying on to the umbo, the highest point on the shell. Although there is some overlap among these three species, *P. ohioensis* and *Potamilus alatus* are clearly less inflated than *P. inflatus*. Slight inflation of the shell provides *P. inflatus* with a minor buoyancy advantage over the other two species in flocculent substratum. In disposal areas that consisted mainly of sand and silt, this can hardly be considered a selective advantage. However, it is possible that heelsplitters could survive in a slurry of sand, silt, and water better than other heavier and less inflated species.

Size demography of populations immediately downriver of Selden Lock and Dam, RM 261.5

Evidence of communitywide recruitment was apparent in the size structure of all populations from which enough individuals were collected to support demographic analysis. All such populations included a few individuals less than 30 mm long.

***Fusconaia ebena*.** The size structure of the dominant population, although biased toward large individuals (SL > 60 mm), nonetheless included recent recruits (Figure 13). Approximately 7 percent of the population sample measured less than 30 mm long. Individuals ranging in length from 68 to 76 mm comprised 72 percent of the sample.

***Quadrula pustulosa*.** A single individual less than 30 mm long was collected. In addition, two other individuals ranging from 30 to 34 mm in length were obtained. However, because only 21 individuals of this species were obtained in quantitative samples, the three small individuals represent

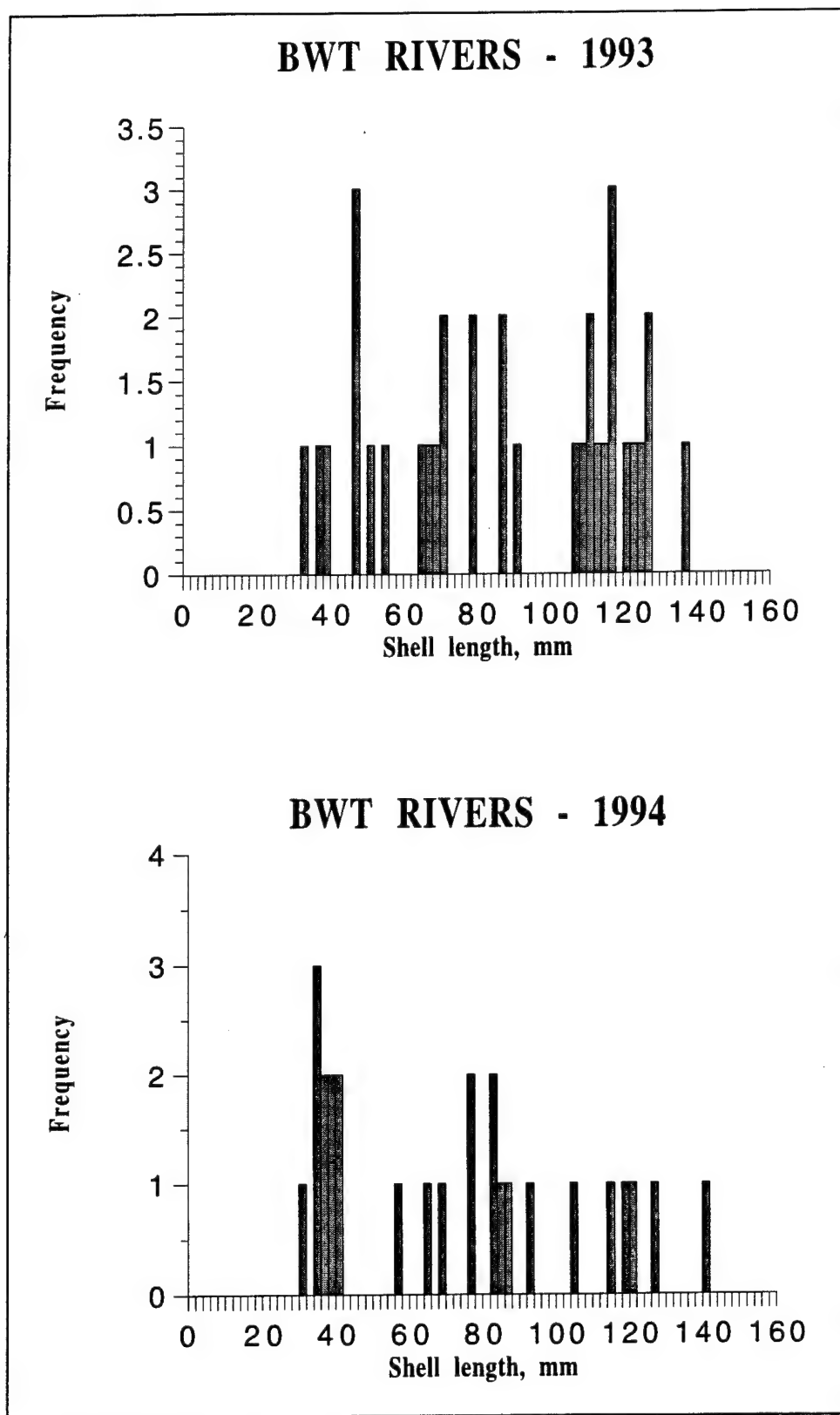


Figure 11. Size demography for *P. inflatus* collected from sand and silt substratum along the BWT rivers, 1993-94

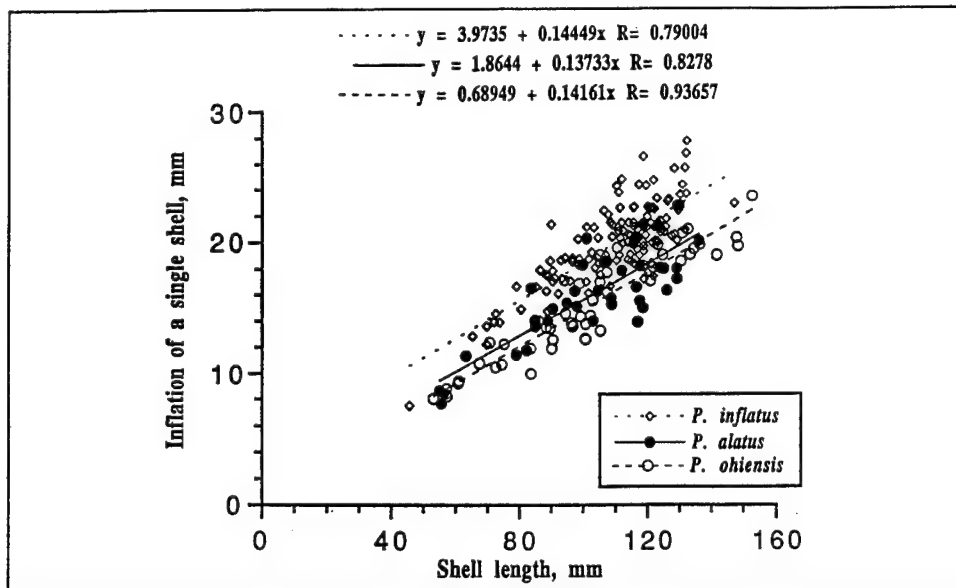


Figure 12. Shell morphometrics for three species of *P. inflatus*

moderately good recent recruitment (i.e., 14 percent of the population). Mussels ranging from 50 to 60 mm long comprised 67 percent of the population sample.

***Obliquaria reflexa*.** The size structure of this population was very similar to that of both *Q. pustulosa* and *F. ebena*. Despite a low total number of individuals (29), two were less than 30 mm long, and one measured 35 mm. The most abundant size class was 52 to 62 mm; this length class included 66 percent of the population sample.

Size demography of populations immediately downriver of Demopolis Lock and Dam, RM 211.9

With respect to size demography of dominant populations, conditions were remarkably similar immediately downriver of Selden Lock and Dam and Demopolis Lock and Dam. All three populations collected in sufficient numbers to support demographic analysis (*F. ebena*, *Q. pustulosa*, and *O. reflexa*) were dominated by larger, older individuals, but also present were some representatives of recent year classes (Figure 14).

***Fusconaia ebena*.** Four of thirty individuals collected were less than 30 mm long. Individuals ranging from 64 to 86 mm comprised the majority of this population. The maximum length was 93 mm.

***Quadrula pustulosa*.** Twenty-four percent of this sample was less than 30 mm long. Thus, this population had slightly stronger evidence of recent recruitment than any at either RMs 211.9 or 261.5. Sixty-seven percent of all mussels obtained ranged in length from 48 to 64 mm.

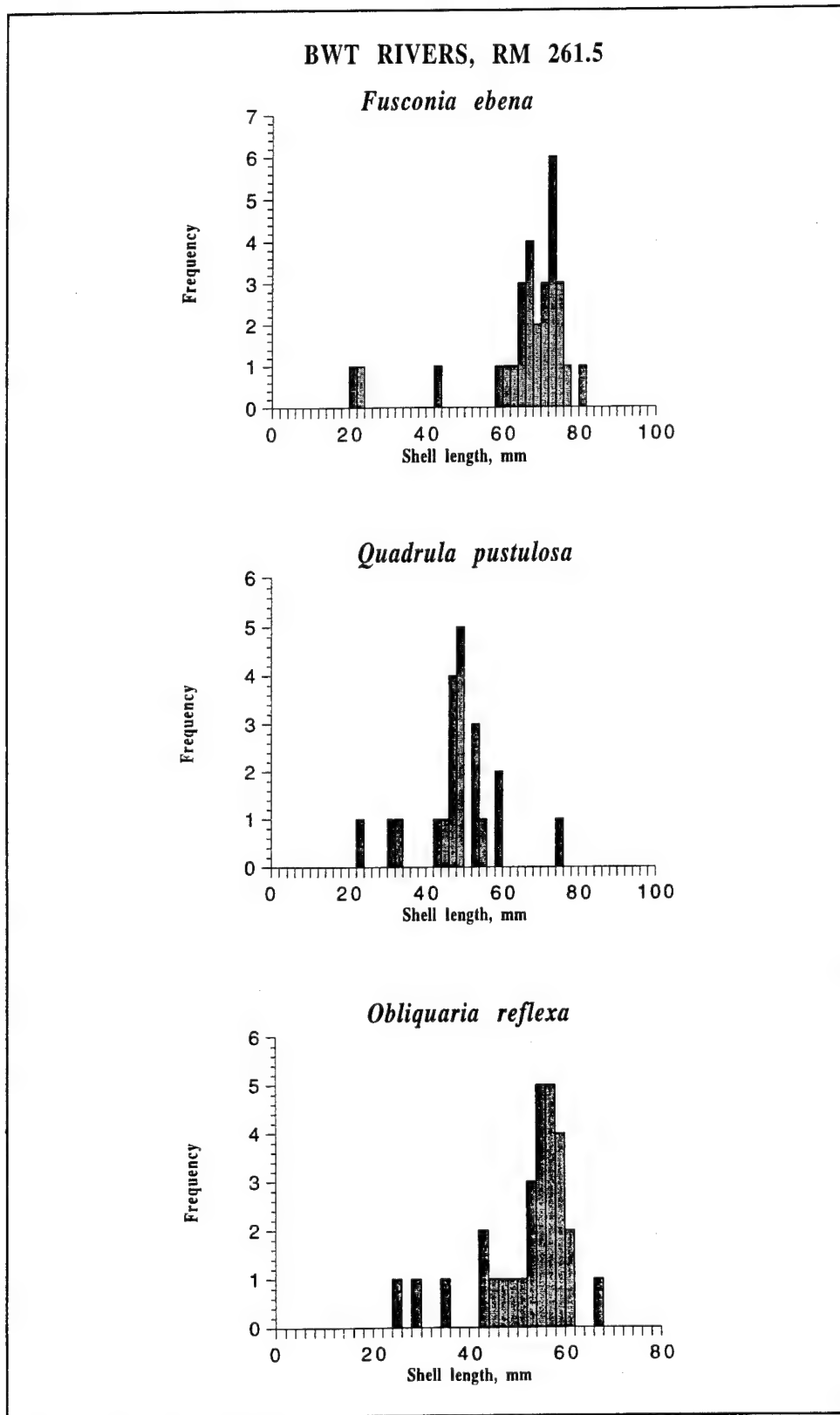


Figure 13. Size demography of three species of Unionidae from four subsites located immediately downriver of Selden Lock and Dam (RM 261.5)

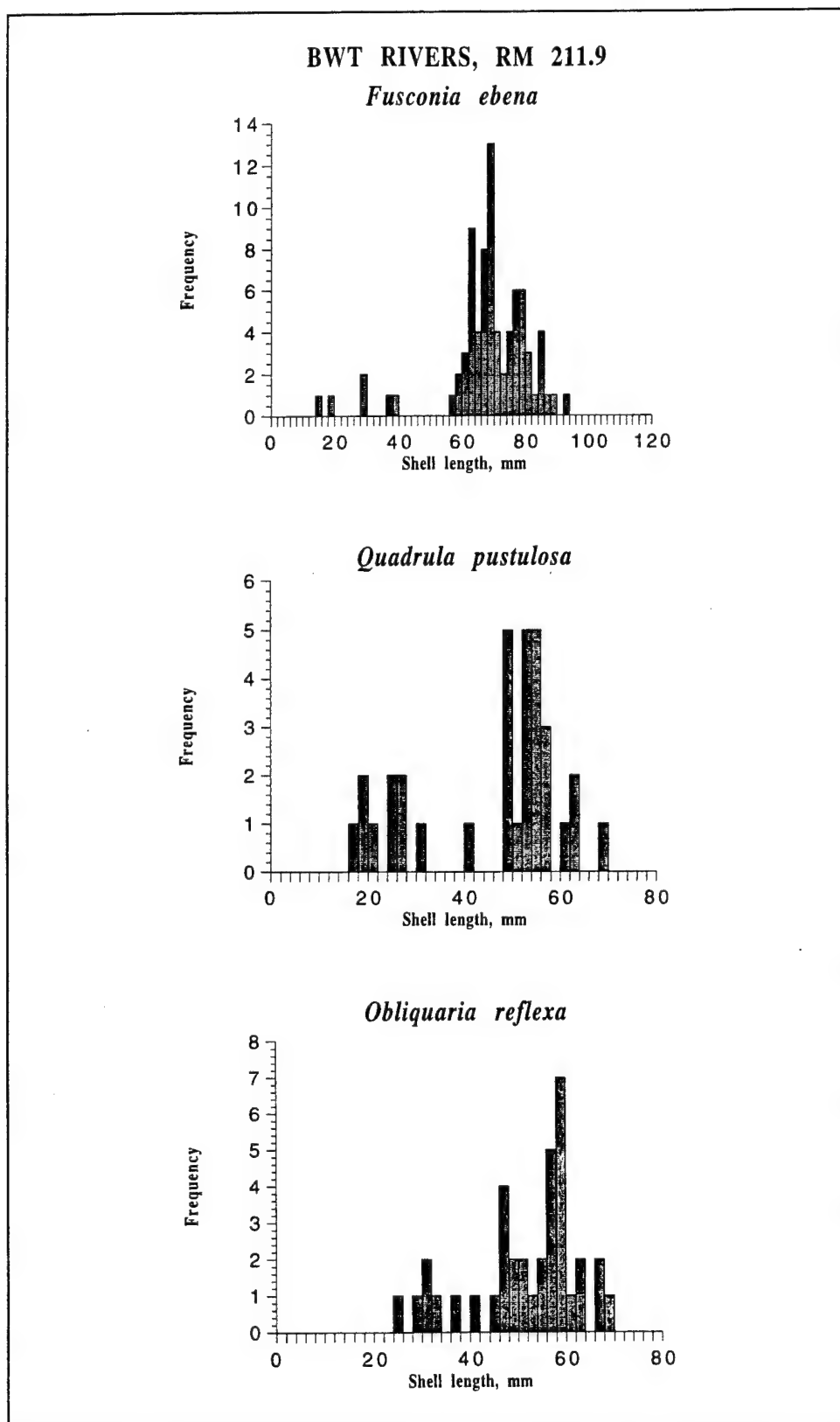


Figure 14. Size demography of three species of Unionidae from four subsites located immediately downriver of Demopolis Lock and Dam (RM 211.9)

Obliquaria reflexa. Eleven percent of this samples measured less than 30 mm. Cohorts were indicated by peaks at 30, 47, and 59 mm, although sample size was not great enough to place much confidence in detailed interpretation of size structure. Mussels associated with the largest apparent peak were the most abundant in the population.

Experiments on Behavior of *P. inflatus*

Background

Live *P. inflatus* were placed in buckets of water and transported to shore. Two types of experiments were conducted to mimic the effects of disturbance because of maintenance dredging. The first was an experiment on reburial to determine the ability of *P. inflatus* to re-enter the substratum if dislodged by dredging or a high-water event. The second experiment was designed to determine the ability of *P. inflatus* to extricate itself from several centimeters of sand and silt. This experiment was designed to mimic conditions when mussels could be buried because of disposal of dredged material or sediment moved by high water.

Reburial

Fourteen live *P. inflatus* between 31.5 and 114.5 mm total SL were tested for their ability to rebury after being dislodged. Mussels were placed on their sides in an aluminum quadrat placed on the substratum in water less than 2 ft deep. Stages in reaching an upright position perpendicular to the substratum were recorded as 22.5, 45, 67.5, and 90 deg (vertical to the substratum). Percentages of the body that were buried were recorded as follows: 25, 50, 75, and 100 percent. Any behavior that was inconsistent with the above stages was recorded. Up to three replicate trials were conducted on approximately half of the mussels. Figures C1-C12, Appendix C, illustrate each trial.

Most of mussels followed a consistent pattern of burial. The pattern began with the mussel extending its pseudopod from its shell into the substratum. Once extended, the mussel expanded the tip of the pseudopod and anchored into the substratum. The individual then began to hoist itself into a vertical position. Once the mussel was vertical, it extended its pseudopod deeper, expanded the tip, and pulled itself deeper. Typically, each mussel paused briefly with only its siphon exposed before becoming completely buried. Occasionally, the mussel became completely buried before it was vertical. Some mussels exhibited considerable lateral movements when only partially buried.

The amount of time required for an individual to initiate reburial (extend its pseudopod) after being placed on its side usually lengthened as subsequent replicates were conducted. The difference in time required to initiate reburial

between consecutive replicates varied from a 27-percent less time to slightly more than 15 times the number of minutes required for the previous replicate.

The amount of time required for *P. inflatus* to become completely buried was independent of the number of replicates conducted. Once the pseudopod was extended, movement to the vertical position and subsequent reburial was largely independent of replicate number. Total time required for *P. inflatus* to rebury after the pseudopod was extended varied from 3.7 to 39.2 min (Figures C1-C12, Appendix C). The amount of time required for reburial was directly related to size of the mussel. Smaller mussels buried themselves more quickly than larger mussels (Figure C13, Appendix C). The time required for mussels between 31.5 and 114.5 mm to become completely reburied can be estimated by using the equation $Y = -5.81X + 0.396$, where "Y" is reburial time and "X" is SL (Standard Error = 1.93).

Results of this study indicate that *P. inflatus* is able to reposition itself in the substratum if dislodged by a dredge or high-water event. This assumes that the mussel is not damaged and is in a position where it can extend its pseudopod to anchor and reposition itself.

Ability of *P. inflatus* to extricate itself from substratum

In this experiment, *P. inflatus* were covered with 10 cm of sand/silt taken from an area immediately adjacent to the quadrat. Their positions were marked with 50-cm stiff wire stakes. The amount of time required for mussels to extricate themselves was to be recorded. However, after several hours, none of the mussels appeared at the substratum-water interface. Each mussel was exhumed and found to be still alive but had not moved. The experiment was terminated. This showed that *P. inflatus* is unable to extricate itself from shallow sand/silt when buried. Results indicate that *P. inflatus* will not be able to extricate itself from at least 4 in. of sand and silt if it is buried by sediments from high water or a maintenance dredging operation.

After both experiments were completed, the *P. inflatus* were returned to the substratum at a site at RM 320.9 that is unaffected by dredging or disposal of dredged material.

Evaluation of Small Boat Channels for Presence of *P. inflatus*

On 10-12 July, small boat channels along the Black Warrior River were surveyed for mussels with special emphasis on *P. inflatus*. Personnel from the Demopolis Lake Resource Office assisted WES personnel with this survey. Dredging sites for small boat navigation was proposed, and personnel from the Mobile District were concerned that this action could harm mussels in the channels. Fifteen of sixteen access channels were located and surveyed.

Fifteen-minute searches for mussels were conducted by WES personnel at each location. All mussels found were placed in labeled bags and later identified.

Sixteen living mussels were found at the 15 sites surveyed. Eight species were collected alive, and two species were represented only by shells (Table 7). *Anodonta grandis* and *Anodonta suborbiculata* are thin-shelled species typically found in sand and silt. *Leptodea fragilis* is another thin-shelled species found in sand, silt, or gravelly sand. The only commercially valuable species present was the washboard, *Megaloniaias nervosa*. The only non-native species collected was the Asiatic clam *Corbicula fluminea*. No specimens of the threatened *P. inflatus* were collected.

All species collected in the small boat channels are common in medium-sized to large rivers in the southeast. Although proposed dredging will adversely affect live mussels, these sites will likely recolonize in the future. Based on the survey conducted at the 15 sites, proposed dredging will not damage any Federally listed threatened or endangered species.

Table 7
Results of a Mussel Survey of Small Boat Access Channels on
the Black Warrior River, 10-12 July 1994 (Right descending bank
= RDB; Left descending bank = LDB)

Location	Species	Living	Shells
Dobb's Swamp RM 217.7, RDB	<i>P. dombeyanus</i>	2	0
Powerline Slough RM 224.8, LDB	<i>A. grandis</i> <i>Leptodia teres</i>	0 2	1 0
Corps Property RM 225.8, RDB	none found	--	--
Candy Landing RM 232.5, LDB	<i>L. teres</i> <i>Q. rumphiana</i>	1 2	0 0
Tindell's Ferry RM 234.4, LDB	none found	--	--
Slough RM 234.7, LDB	none found	--	--
Area 19 RM 235.2, LDB	location not found		
Slough RM 235.5, LDB	<i>C. fluminea</i>	1	0
Slough RM 237.8, LDB	<i>L. teres</i>	3	0
Slough RM 238.4, LDB	<i>A. suborbiculata</i> <i>C. fluminea</i>	3 1	0 0
Area 18 RM 240.7, RDB	none found	--	--
Slough Rm 242.5, RDB	<i>L. teres</i> <i>M. nervosa</i>	1 1	0 0
Needham Creek RM 249.2, RDB	none found	--	--
Slough RM 249.3, RDB	none found	--	--
Buckman's Landing RM 250.5, LDB	none found	--	--
Slough RM 253.1, LDB	<i>L. fragilis</i> <i>Potamilus purpurata</i>	1 0	0 1

4 Discussion

Characterization of *P. inflatus* Habitat in the BWT Rivers

This study was conducted to provide specific information for Mobile District personnel (see the Introduction to this report). All of those information needs have been answered, and no new information (with the possible exception of certain site-specific studies) will be required. Results of this study, and a study conducted in 1993 (Miller 1994), should answer basic questions on *P. inflatus* required for most permit-related questions in the BWT rivers.

Community characteristics

Total species richness at the two gravel bars below locks and dams (13 species) and in the disposal areas along the shore (a total of 7 species of native mussels based on the 1993 survey) is less than found in most medium-sized to large rivers. At a gravel bar in the lower Ohio River near Olmsted, IL, 23 species of mussels were identified. In a survey of a gravel bar in the lower Tennessee River, 4,768 individuals were collected and 23 species were identified (Miller, Payne, and Tippit 1992). In the east channel of the upper Mississippi River near Prairie du Chien, WI (RM 635), there are approximately 30 species (Miller and Payne 1993a).

The unionid fauna of most large-river mussel beds is dominated by 2 or 3 species. Based on quantitative sampling, beds below Demopolis Lock and Dam and Selden Lock and Dam were dominated by *F. ebena* and *Quadrula pustulosa pustulosa*, which together comprised 50 to 60 percent of the unionid fauna. These bars are similar to a bed in the middle Ohio River near Cincinnati, OH, where the fauna was dominated by *Pleurobema cordatum* and *Q. p. pustulosa*, which together comprised 39.9 percent of the assemblage (Miller and Payne 1993b). At the bed in the lower Tennessee River, the fauna was dominated by *A. p. plicata* (39.4 percent) and *Fusconaia ebena* (39.4 percent) (Miller, Payne, and Tippit 1992).

Sand/silt substratum along the BWT rivers was dominated by *P. inflatus*, which comprised more than 50 percent of the fauna. Although this species

dominated, its density was several orders of magnitude less than in the gravel bars immediately downriver of the two locks and dams. *Potamilus inflatus* comprised less than 1 percent of the assemblage in gravel/sand substratum as compared with sand and silt along the BWT rivers.

Density

In comparison with other large-river mussel beds, mean total unionid density (18.1 and 8.8 individuals/m²) immediately downriver of Demopolis Lock and Dam and Selden Lock and Dam can be considered low. At an inshore and offshore site in the lower Tennessee River sampled in 1986 (32 quantitative samples were collected at each), total mussel density was 187.7 and 79.7 individuals/m², respectively (Way, Miller, and Payne 1989). In the middle Ohio River near Cincinnati, mussel density ranged from 4.4 to 52.4 individuals/m² (Miller and Payne 1993b). In a survey of the upper Mississippi River at locations between RMs 250 and 635, Miller et al. (1990) reported that total mussel density ranged from 5.2 to 333.2 individuals/m² at 16 sites (10 quantitative samples were taken at each). At half of the sites, total density was greater than 50 individuals/m², and at four sites it was greater than 100 individuals/m².

Density of *P. inflatus* in sand/silt substratum along the BWT rivers, 0.5 and 0.97 individuals/100 m² at sites affected and unaffected by material disposal in 1993 is extremely low. Many collectors and commercial fisherman would not work a bed with mussels less dense than one individual/m². Although numerical densities are low, the total number of inflated heelsplitters at any one disposal area could be as many as several hundred (Miller 1994).

Based on information collected in 1993 and 1994, the densest populations of *P. inflatus* were found between RMs 323.3 and 300.9. This reach of the BWT rivers has a lower gradient than the reach immediately upriver, RMs 334.0 to 323.5. The mean slope (change in elevation per river mile) for the four river reaches studied in 1993 were calculated (see below). The reach with the highest density of *P. inflatus* (1.73 individuals/100 m², taken from the 1993 study, see Miller 1994) had a comparatively low gradient.

River Reach	Mean Slope, ft/mile	Density of <i>P. inflatus</i>
223.0-323.5	0.9	0.09
323.3-300.9	0.4	1.73
295.0-187.6	0.4	0.39
107.0-65.4	0.5	0.00

Evidence of recent recruitment

The number of individuals and species less than 30-mm total SL provides an estimate of recent recruitment. Individuals of this size are approximately 2 to 3 years old, and their presence indicates that conditions were appropriate for successful recent reproduction. The overall percentage of native (excluding *C. fluminea*) bivalves less than 30-mm total SL was 9.4 and 7.9 percent, and the overall percentage of species less than 30-mm total SL was 35.7 and 71.4 percent at Demopolis Lock and Dam and Selden Lock and Dam, respectively (Tables 4 and 5).

Potamilus inflatus exhibited evidence of recent recruitment in the sand/silt substratum at disposal areas and areas unaffected by disposal (Figure 11). At RM 326.9, which was dredged in 1993, two inflated heelsplitters approximately 25 mm long and a single adult-sized specimen were collected. This indicates that mussels can be carried into these disposal areas by high flow and that recruitment can occur soon after the area is stabilized.

Occasionally, mussel beds are surveyed that exhibit evidence of very strong recent recruitment. At a mussel bed in the lower Ohio River, a single cohort of *F. ebena* with an average shell length of 15.8 mm represented 71 percent of the population (Payne and Miller 1989). However, several years passed before strong recruitment for this species was noted. Successful stocks of freshwater mussels (and other long-lived species) can be sustained without annual recruitment.

Presence of *Dreissena polymorpha*

The first report of the zebra mussel (*Dreissena polymorpha*) in North America was from Lake St. Clair in June 1988 (Hebert, Muncaster, and Mackie 1989). By late summer 1989, zebra mussels had spread downstream into the Detroit River, Lake Erie, Niagara River, and western Lake Ontario (Griffiths, Kovalak, and Schloesser 1989). By late September 1990, zebra mussels had spread through Lake Ontario and down the St. Lawrence River to Massena, NY. In June 1991, biologists from the Illinois Natural History Survey found adult zebra mussels at Illinois RM 50, 60, and 110 (Moore 1991; Sparks and Marsden 1991).

By early January 1993, zebra mussels had spread throughout most of the inland waterway system. They probably reached upriver sites on hulls of commercial navigation vessels (Keevin, Yarbrough, and Miller 1992). They were found in the lower Mississippi River as far south as Vicksburg, MS, and in the upper Mississippi River near St. Paul, MN.¹

¹ *Dreissena polymorpha* Information Review 1992. Published by the Zebra Mussel Information Clearing House of New York Sea Grant.

There is every reason to believe that this species will continue to spread throughout North America where suitable habitat exists (Strayer 1990). However, no zebra mussels were found during the 1993 or 1994 survey. Since this species has been collected in the Tennessee River, it is likely that they will soon reach the BWT rivers. Effects on native mussels, including inflated heelsplitters, are likely to be negative. This is unlike the case of *C. fluminea*-unionid interactions, which are not always adverse (Miller and Payne 1994).

An Evaluation of *P. inflatus* in the BWT Rivers

Based upon the survey of 1993 and 1994, the following conclusions can be made:

Presence of *P. inflatus* in river reaches unaffected by dredging

Divers surveyed two reaches of the BWT rivers where dredged material has never been placed: between the Alabama Highway 43 and I-59 bridges and immediately downriver of the Moundville boat ramp, RM 303, right descending bank. Density of *P. inflatus* at areas that had never been dredged was approximately double that in areas dredged in 1993. It is noteworthy that areas dredged in 1993 recolonized to approximately 50 percent that of undisturbed areas in less than a year.

Presence of *P. inflatus* in stable gravel bars unaffected by dredging

Mussels were collected using qualitative and quantitative methods in gravel and sand immediately downriver of Demopolis Lock and Dam and Selden Lock and Dam. The inflated heelsplitter comprised about 1 percent of the community in these beds. Hartfield (1988a,b) reported that *P. inflatus* was only found in sand and silt. Although this species dominated the mollusc community in sand and silt, its greatest density occurred in stable gravel sand substratum.

Reinvasion of recently dredged areas in the BWT rivers

Divers searched a sand bar at RM 326.9 that had dredged material placed on it in 1993. They found two inflated heelsplitters that were about 25 millimeters (1 in.) long and slightly more than 1 year old. These mussels clearly had a single growth ring, plus a few millimeters beyond that ring that provided evidence of growth in early 1994. It is apparent that these individuals are the result of recruitment early in 1993. In addition, divers found adult-sized inflated heelsplitters. These mussels had either washed in after disposal or else had survived the disposal process. It is most likely that they were carried into the disposal area by high flow after dredging.

Findings suggest that the inflated heelsplitter rapidly reinvades recently disturbed sand bars. This is accomplished by natural recruitment (the immature mussels being dropped by a host fish) and by juvenile or adult mussels being carried in by river currents.

Ability of inflated heelsplitters to reburrow into substratum

A series of tests were conducted to determine the ability of heelsplitters to reburrow into the substratum after being dislodged. Depending on size, a mussel took from 5 to 90 min to completely rebury. Small mussels moved quickly; the larger individuals required the longest time. There was some variability in burrowing rates among individuals of the same size. The speed was dependant on the substratum; rates were low in areas with firmly packed sand. It is apparent that specimens ejected from the substratum by high water or dredging have the ability to quickly reburrow if suitable substratum is present.

Ability of heelsplitter to extricate itself after being buried in sand

Experiments were conducted to evaluate the ability of mussels to extricate themselves after being buried in sand either 4 or 6 in. deep. Experiments had to be terminated after 4 to 6 hr. Mussels had moved very little, and it was apparent that they were not going to reach the substratum-water interface. Based on these results, it is likely that mussels burrowing by disposal are unlikely to be able to extricate themselves and will likely perish.

Presence of inflated heelsplitters at RMs 327.2-327.3

The embayment between RMs 327.2 and 327.3 was searched in 1993 by the FWS. Personnel of the FWS reported high numbers of common mussels and inflated heelsplitters. These authors concur with this assessment although density estimates were made. However, this area is not similar to those along the shore of the BWT rivers surveyed in 1993 and 1994. This is an embayment that is protected from high-velocity water. Data from this location should not be compared with results obtained where dredged material is disposed.

Lack of high-density populations of *P. inflatus* in the BWT rivers

No areas in the BWT rivers were found that supported extremely high densities of inflated heelsplitters that could be sources of this species for other reaches of the BWT rivers. When present, this species is uncommon. The success of *P. inflatus* in the BWT rivers is probably related to its rapid growth rates and ability to quickly reburrow if dislodged by high water or other disturbances.

Effects of disposal of dredged material on inflated heelsplitters in the BWT rivers

The inflated heelsplitter mussel was found in extremely low densities, although it was the dominant species, at dredged material disposal areas. Disposal areas used less than 12 months earlier were rapidly recolonized by inflated heelsplitters. Within 1 year, densities were approximately 50 percent as high as areas that were totally unaffected by disposal of dredged material.

References

- Burch, J. B. (1975). "Freshwater Unionacean clams (Mollusca: Pelecypoda) of North America," Malacological Publications, Hamburg, MI.
- Green, R. H. (1979). *Sampling design and statistical methods for environmental biologists*. John Wiley & Sons, New York.
- Griffiths, R. W., Kovalak, W. P., and Schloesser, D. W. (1989). "The zebra mussel, *Dreissena polymorpha* (Pallas, 1771), in North America: Impacts on raw water users." *Symposium: Service water system problems affecting safety-related equipment*. Charlotte, North Carolina, Nuclear Power Division, Electric Power Research Institute, Palo Alto, CA, 11-26.
- Hartfield, P. (1988a). "Status survey for the Alabama heelsplitter mussel, *Potamilus inflatus* (Lea 1831)," Report to the U.S. Fish and Wildlife Service.
- _____. (1988b). "Mussel Survey for the Amite River, Louisiana, 9-13 May 1988," Prepared for Espey Huston & Associates, Inc., Jackson, MS.
- Hebert, P. D. N., Muncaster, B. W., and Mackie, G. L. (1989). "Ecological and genetic studies on *Dreissena polymorpha* (Pallas): A new mollusc in the Great Lakes," *Canadian Journal of Fisheries and Aquatic Sciences* 46, 1587-1591.
- Hurlbert, S. H. (1984). "Pseudoreplication and the design of ecological field experiments," *Ecological Monographs* 54, 187-211.
- Isom, B. G., and Gooch, C. (1986). "Rationale and sampling design for fresh-water mussels, Unionidae, in streams, large rivers, impoundments, and lakes." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. STM STP 894, B. G. Isom, ed., American Society for Testing and Materials, Philadelphia, PA, 46-59.

- Keevin, T. M., Yarbrough, R. E., and Miller, A. C. (1992). "Long-distance dispersal of zebra mussels (*Dreissena polymorpha*) attached to hulls of commercial vessels," *Journal of Freshwater Ecology* 7(4), 437.
- Kovalak, W. P., Dennis, S. D., and Bates, J. M. (1986). "Sampling effort required to find rare species of freshwater mussels." *Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems*. STM STP 894, B. G. Isom, ed., American Society for Testing and Materials, Philadelphia, PA, 34-45.
- Miller, A. C. (1994). "A Survey of the Black Warrior and Tombigbee rivers, Alabama, for the threatened inflated heelsplitter mussel, *Potamilus inflatus*, May 1993," Technical Report EL-94-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Miller, A. C., and Nelson, D. (1983). "Instruction report on freshwater mussels," Instruction Report EI-83-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Miller, A. C., and Payne, B. S. (1988). "The need for quantitative sampling to characterize size demography and density of freshwater Mussel Communities," *Bulletin of the American Malacological Union, Inc.* 6, 49-54.
- _____. (1993a). "The effects of commercial navigation traffic on freshwater mussels in the Upper Mississippi River: 1991 studies," Technical Report EL-93-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- _____. (1993b). "Qualitative versus quantitative sampling to evaluate population and community characteristics at a large-river mussel bed," *The American Midland Naturalist* 130, 133-145.
- _____. (1994). "Co-occurrence of native freshwater mussels (Unionidae) and the nonindigenous *Corbicula fluminea* at two stable shoals in the Ohio River," *Malacological Review* 27, 87-97.
- Miller, A. C., Payne, B. S., Hornbach, D. J., and Ragland, D. V. (1990). "An investigation of the physical effects of increased commercial navigation traffic on freshwater mussels in the Upper Mississippi River: Phase I studies," Technical Report EL-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Miller, A. C., Payne, B. S., Shafer, D. J., and Neill, L. T. (1994). "Techniques for monitoring freshwater bivalve communities and populations in large rivers." *Proceedings of the conservation and management of freshwater mussels, October 12-14, 1992, St. Louis, MO.* 147-158.

- Miller, A. C., Payne, B. S., and Tippit, R. (1992). "Characterization of a freshwater mussel (Unionidae) community immediately downriver of Kentucky Lock and Dam in the Tennessee River," *Transactions of the Kentucky Academy of Sciences* 53(3-4), 154-161.
- Moore, S. G. (1991). "Zebra mussels enter riverine systems," *Dreissena polymorpha Information Review* 2(4), 9.
- Murray, H. D., and Leonard, A. B. (1962). *Handbook of unionid mussels in Kansas*. Museum of Natural History, University of Kansas, Lawrence, KS.
- Parmalee, P. W. (1967). "The fresh-water mussels of Illinois," Illinois State Museum Popular Science Series 8, 1-108.
- Payne, B. S., and Miller, A. C. (1989). "Growth and survival of recent recruits to a population of *Fusconaia ebena* (Bivalvia: Unionidae) in the lower Ohio River," *American Midland Naturalist* 121, 99-104.
- Sparks, R., and Marsden, E. (1991). "Zebra mussel alert," *Illinois Natural History Survey Reports* 310, 1-2.
- Stewart, J. H. (1993). "Inflated heelsplitter *Potamilus inflatus* recovery plan," U.S. Fish and Wildlife Service, Jackson, MS.
- Strayer, D. L. (1990). "Projected distribution of the zebra mussel, *Dreissena polymorpha*, in North America," *Canadian Journal of Fisheries and aquatic Sciences* 48, 1389-1395.
- Starrett, W. C. (1971). "A survey of the mussels (Unionidae) of the Illinois River: A polluted stream," *Illinois Natural History Survey Bulletin* 30(5), 266-403.
- Stem, E. M. (1976). "The freshwater mussels (Unionidae) of the Lake Maurepas-Ponchartrain-Borgne Drainage System, Louisiana and Mississippi," Ph.D. diss., Louisiana State University, Baton Rouge.
- Turgeon, D. D., Bogan, A. E., Coan, E. V., Emerson, W. K., Lyons, W. G., Pratt, W. L., Roper, C. F. E., Scheltema, A., Thompson F. G., and Williams, J. D. (1988). "Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks," Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union, Bethesda, MD.
- U.S. Army Corps of Engineers. (1987). "Final Supplement Impact Statement Black Warrior and Tombigbee Rivers, Alabama (maintenance)," U.S. Army Engineer District, Mobile, Mobile, AL.

U.S. Fish and Wildlife Service. (1991). "Endangered and threatened wildlife and plants," *Federal Register*, July 15, 1991, 50 CFR 17.11 and 17.12.

Way, C. M., Miller, A. C., and Payne, B. S. (1989). "The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River," *The Nautilus* 103, 96-98.

Appendix A
Summary Information on
***Potamilus inflatus*, Black**
Warrior and Tombigbee Rivers,
July 1994

Table A1
Information on *P. Inflatus* Collected Using Semiquantitative
Methods from the BWT Rivers, 1994

Date	Dive No.	River Mile	Number of <i>P. Inflatus</i>	Time min	Col Rate No./min	No./100 m ²	Site Description
7 Jul	24	327.2	4	30	0.133	2.66	High-density site reported by USFWS, never dredged
7 Jul	25	327.2	0	30	0.000	0.0	High-density site reported by USFWS, never dredged
7 Jul	21	326.9	0	30	0.000	0.0	12 Mile Rock, dredged in 1993
7 Jul	20	326.9	0	30	0.000	0.0	12 Mile Rock, dredged in 1993
7 Jul	22	326.9	2	30	0.067	1.34	12 Mile Rock, dredged in 1993
7 Jul	23	326.9	2	30	0.067	1.34	12 Mile Rock, dredged in 1993
7 Jul	19	322.3	1	30	0.033	0.33	323 Bar, dredged in 1993
7 Jul	16	322.6	1	30	0.033	0.33	323 Bar, dredged in 1993
7 Jul	17	322.3	0	30	0.000	0.0	323 Bar, dredged in 1993
7 Jul	18	322.0	0	30	0.000	0.0	323 Bar, dredged in 1993
7 Jul	13	320.9	3	30	0.100	2.00	Between H'Way 42 & I-59 bridge, never dredged
7 Jul	15	320.9	1	30	0.033	0.66	Between H'Way 42 & I-59 bridge, never dredged
7 Jul	14	320.9	3	30	0.100	2.00	Between H'Way 42 & I-59 bridge, never dredged
6 Jul	10	309.4	2	30	0.067	1.34	Hulls Bar, dredged in 1993
6 Jul	7	309.2	0	30	0.000	0.00	Hulls Bar, dredged in 1993
6 Jul	9	309.0	0	30	0.000	0.00	Hulls Bar, dredged in 1993
6 Jul	8	308.9	0	30	0.000	0.00	Hulls Bar, dredged in 1993
6 Jul	6	304.1	2	30	0.067	1.34	McGowin Bluff, dredged in 1993
6 Jul	5	303.9	0	31	0.000	0.00	McGowin Bluff, dredged in 1993
6 Jul	11	303.8	0	30	0.000	0.00	McGowin Bluff, dredged in 1993
6 Jul	12	303.8	2	30	0.067	1.34	McGowin Bluff, dredged in 1993
6 Jul	1	303.3	0	28	0.000	0.00	Immediately downriver of Moundville, never dredged
6 Jul	2	303.1	2	28	0.071	1.42	Immediately downriver of Moundville, never dredged
6 Jul	3	302.9	1	29	0.034	0.68	Immediately downriver of Moundville, never dredged
6 Jul	4	302.8	0	33	0.000	0.00	Immediately downriver of Moundville, never dredged

Table A2
Summary Statistics on Substratum Characteristics, Numbers of *P. Inflatus* Collected, Water Depth, and Site Characteristics, BWT Rivers Survey, 1994

Date	Dive No.	RM	Sample No.	Grain Size, mm					Depth	No. of PI	Notes on Location
				<0.075	0.075-0.424	0.425-0.1.999	2.00-4.740	>4.750			
6 Jul	2	303.1	1.0	2.8	95.5	1.7	0.0	0	7		Immediately downriver of Moundville, never dredged
6 Jul	2	303.1	2.0	2.9	95.4	1.7	0.0	0	7	2	Immediately downriver of Moundville, never dredged
6 Jul	3	302.9	3.0	19.9	79.4	0.7	0.0	0	11	1	Immediately downriver of Moundville, never dredged
6 Jul	6	304.1	4.0	78.2	21.4	0.4	0.0	0	7	1	McGowin Bluff, dredged in 1993
6 Jul	6	304.1	5.0	50	49.3	0.7	0.0	0	7	1	McGowin Bluff, dredged in 1993
6 Jul	10	309.4	6.0	13.1	57.4	2.6	4.3	22.6	5	0	Hulls Bar, dredged in 1993
6 Jul	10	309.4	8.0	34.9	63.3	1.8	0.0	0	10	2	Hulls Bar, dredged in 1993
6 Jul	10	309.4	7.0	39.3	60.2	0.5	0.0	0	8	0	Hulls Bar, dredged in 1993
6 Jul	12	303.9	9.0	17.6	77.4	5.0	0.0	0	5	2	McGowin Bluff, dredged in 1993
7 Jul	13	320.9	10.0	77.2	22.4	0.4	0.0	0	18	1	Between H'Way 42 and I-59 bridges, never dredged
7 Jul	13	320.9	12.0	57.3	42.2	0.5	0.0	0	17	1	Between H'Way 42 and I-59 bridges, never dredged
7 Jul	13	320.9	11.0	65.3	33.8	0.9	0.0	0	12	1	Between H'Way 42 and I-59 bridges, never dredged
7 Jul	14	320.9	13.0	19.6	72.2	8.2	0.0	0	17	1	Between H'Way 42 and I-59 bridges, never dredged

(Continued)

Table A2 (Concluded)

Date	Dive No.	RM	Sample No.	Grain Size, mm					Depth	No. of PI	Notes on Location
				<0.075	0.075-0.424	0.425-0.1.999	2.00-4.740	>4.750			
7 Jul	14	320.9	14.0	37.5	61.6	0.9	0.0	0	17	1	Between H'Way 42 and I-59 bridges, never dredged
7 Jul	14	320.9	15.0	35.9	63.6	0.5	0.0	0	5	1	Between H'Way 42 and I-59 bridges, never dredged
7 Jul	16	322.6	16.0	2.3	95.9	1.8	0.0	0	13	1	323 Bar, dredged in 1993
7 Jul	19	322.3	17.0	5.1	92	2.9	0.0	0	9	1	323 Bar, dredged in 1993
7 Jul	20	326.9	18.0	2	94.1	3.9	0.0	0	9	0	323 Bar, dredged in 1993
7 Jul	22	326.9	21.0	27.7	71.2	1.1	0.0	0	8	2	12 Mile Rock, dredged in 1993
7 Jul	23	326.9	19.0	3	90.7	6.3	0.0	0	14	1	12 Mile Rock, dredged in 1993
7 Jul	23	326.9	20.0	58	41.7	0.3	0.0	0	3	1	12 Mile Rock, dredged in 1993
7 Jul	24	327.2	23.0	38.5	61.2	0.3	0.0	0	7	1	High-density site reported by USFWS, never dredged
7 Jul	24	327.2	22.0	17.7	81.2	1.1	0.0	0	4	3	High-density site reported by USFWS, never dredged

Appendix B Summary Statistics and Graphical Presentation of Selected Water Velocity Measurements, Black Warrior River, July 1994

Table B1
Summary Statistics for Selected Water Velocity Measurements,
6 July 1994, Black Warrior River (ft/s = feet/second)

Trial Number: 1
6 Jul 94; 12:55-13:13
River Mile 309.2, RDB
Water Depth = 1.5 m

Parameter	X-Axis, ft/s	Y-Axis, ft/s	Net Velocity, ft/s	Direction of Flow, Deg
Average	0.661	0.589	0.885	245.1
Minimum	0.549	0.489	0.752	215.9
Maximum	0.777	0.685	1.023	267.8
Range	0.228	0.196	0.271	51.9
Standard Error	0.0016	0.0015	0.0021	0.4
Number of Points	1,089	1,089	1,089	1,089

Trial Number 3
6 Jul 94; 14:57-14:59
River Mile 309.2, RDB
Water Depth = 2.0 m

Parameter	X-Axis, ft/s	Y-Axis, ft/s	Net Velocity, ft/s	Direction of Flow, Deg
Average	0.995	0.539	1.132	96.1
Minimum	0.922	0.438	1.042	84.5
Maximum	1.122	0.651	1.296	105.9
Range	0.200	0.213	0.254	21.4
Standard Error	0.0041	0.0038	0.0052	0.4
Number of Points	129	129	129	129

Table B2
Summary Statistics for Selected Water Velocity Measurements,
7 July 1994, Black Warrior River

Trial Number: 1
7 Jul 94; 14:05-14:20
River Mile 326.9, LDB
Water depth = 2.5 m

Parameter	X-Axis, ft/s	Y-Axis, ft/s	Net Velocity, ft/s	Direction of Flow, Deg
Average	0.043	0.591	0.596	49.9
Minimum	-0.115	0.478	0.479	37.0
Maximum	0.226	0.070	0.709	66.1
Range	0.341	-0.408	0.230	29.1
Standard Error	0.0025	0.0016	0.0017	0.2
Number of Points	854	854	854	854

Trial Number 3
7 Jul 94; 16:08-16:16
River Mile 326.9, LDB
Water depth = 2.0 m

Parameter	X-Axis, ft/s	Y-Axis, ft/s	Net Velocity, ft/s	Direction of Flow, Deg
Average	0.628	0.464	0.782	61.5
Minimum	0.509	0.327	0.607	56.0
Maximum	0.732	0.581	0.933	68.4
Range	0.223	0.254	0.326	12.4
Standard Error	0.0023	0.0027	0.0034	0.1
Number of Points	499	499	499	499

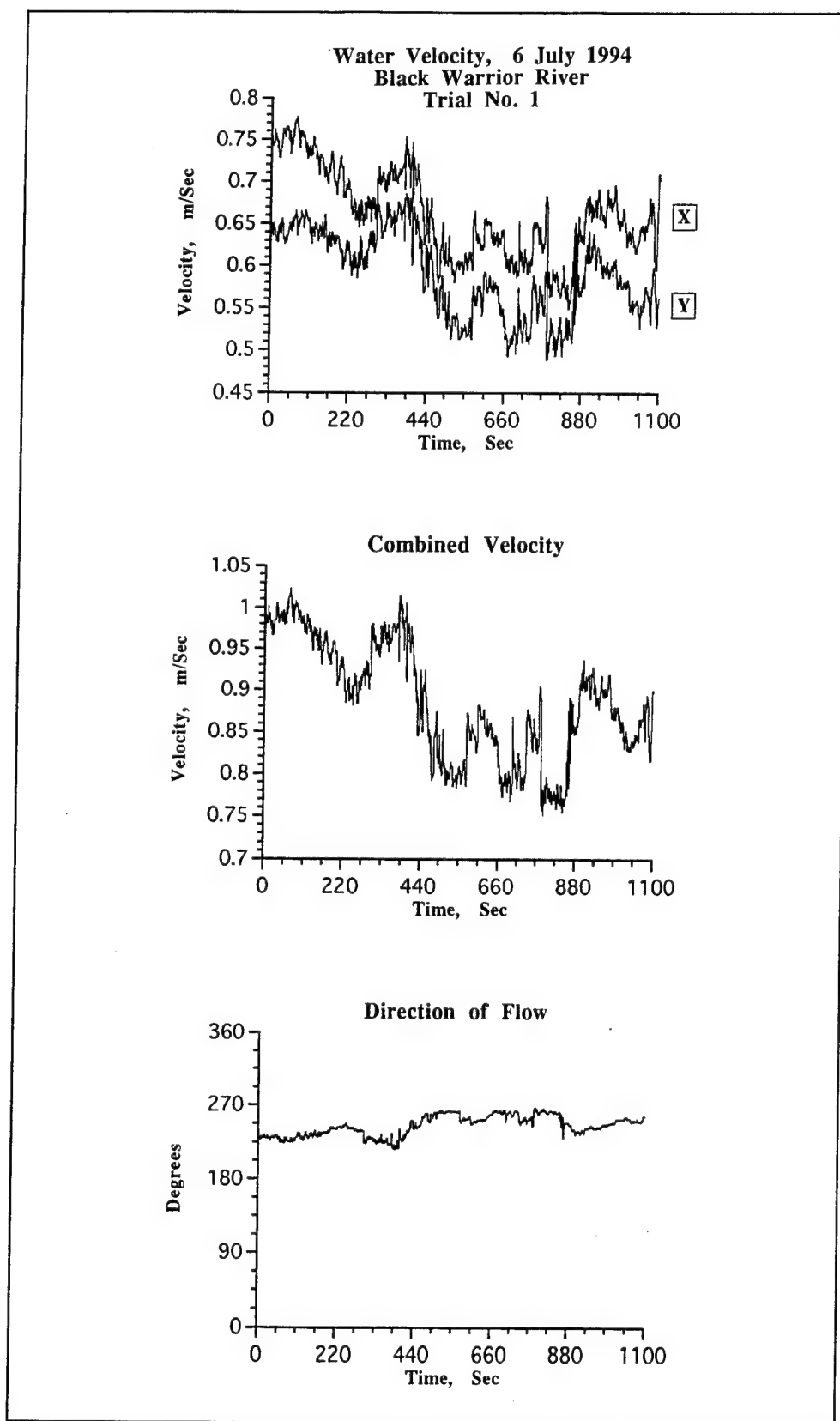


Figure B1. Single axis velocity, net velocity, and direction of flow for Trial No. 1, RM 309.2 RDB, 6 July 1994, 12:55-13:13

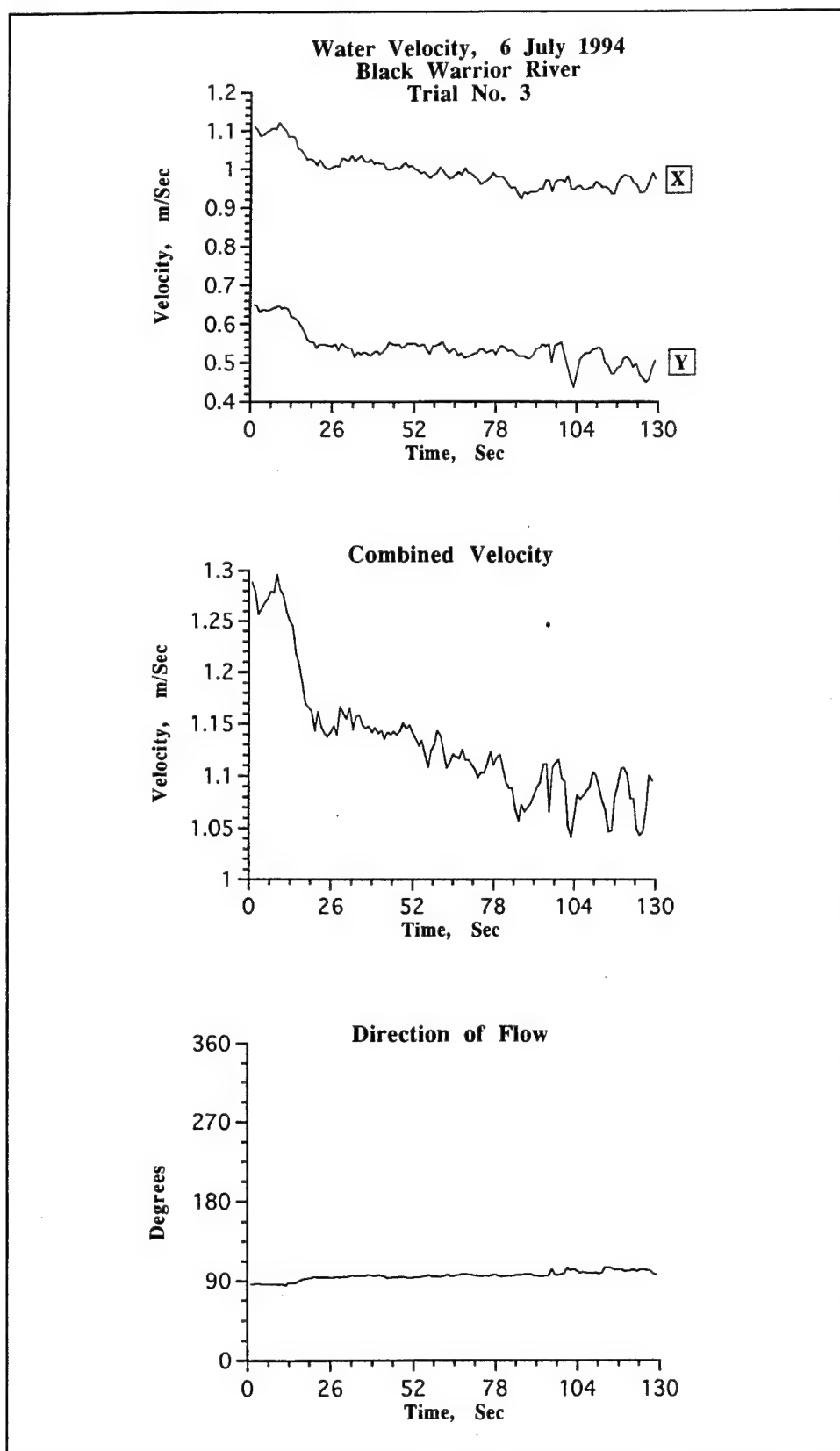


Figure B2. Single axis velocity, net velocity, and direction of flow for Trial No. 3, RM 309.2 RDB, 6 July 1994, 14:57-14:59

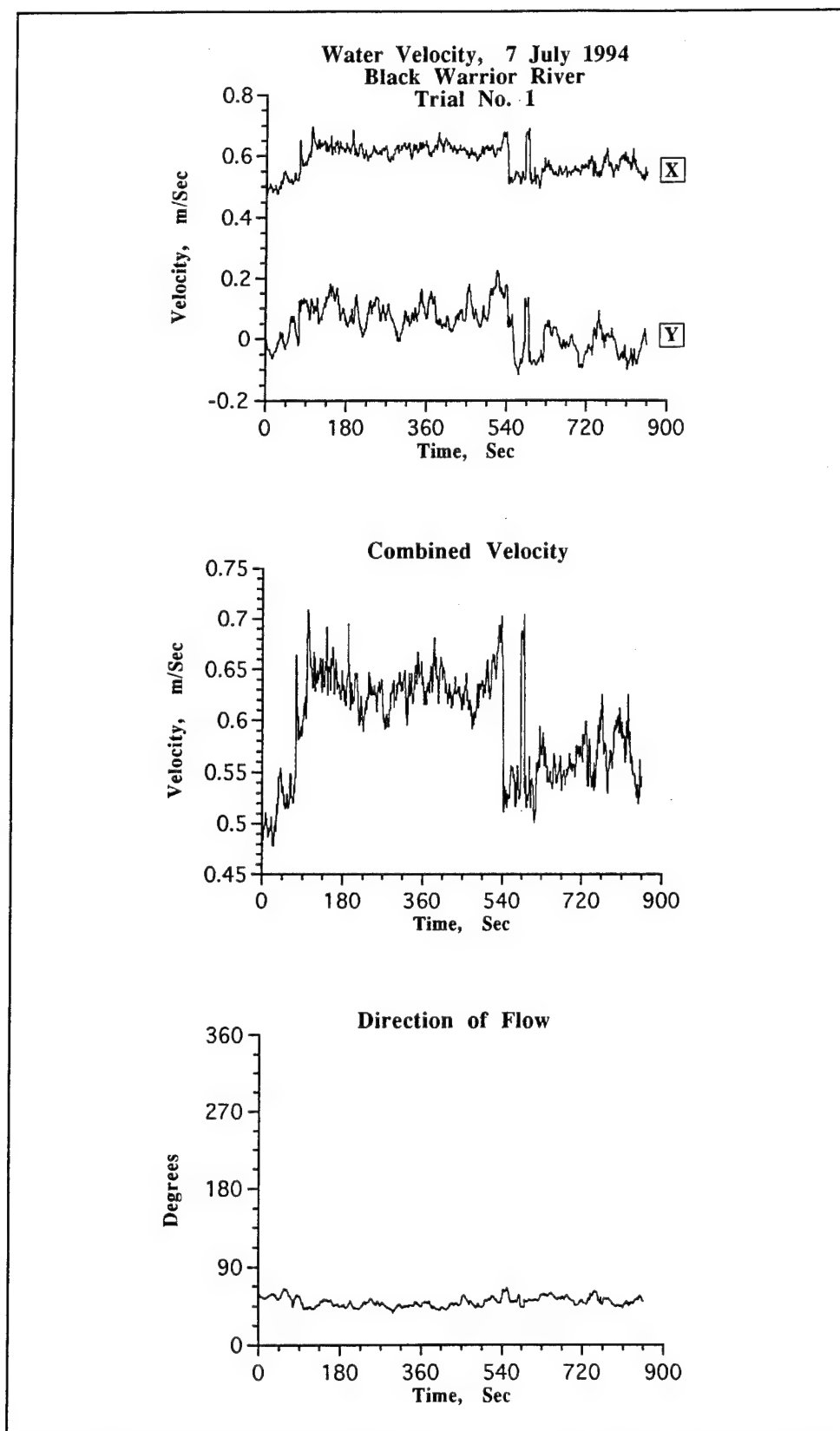


Figure B3. Single axis velocity, net velocity, and direction of flow for Trial No. 1, RM 326.9 LDB, 7 July 1994, 14:05-14:20

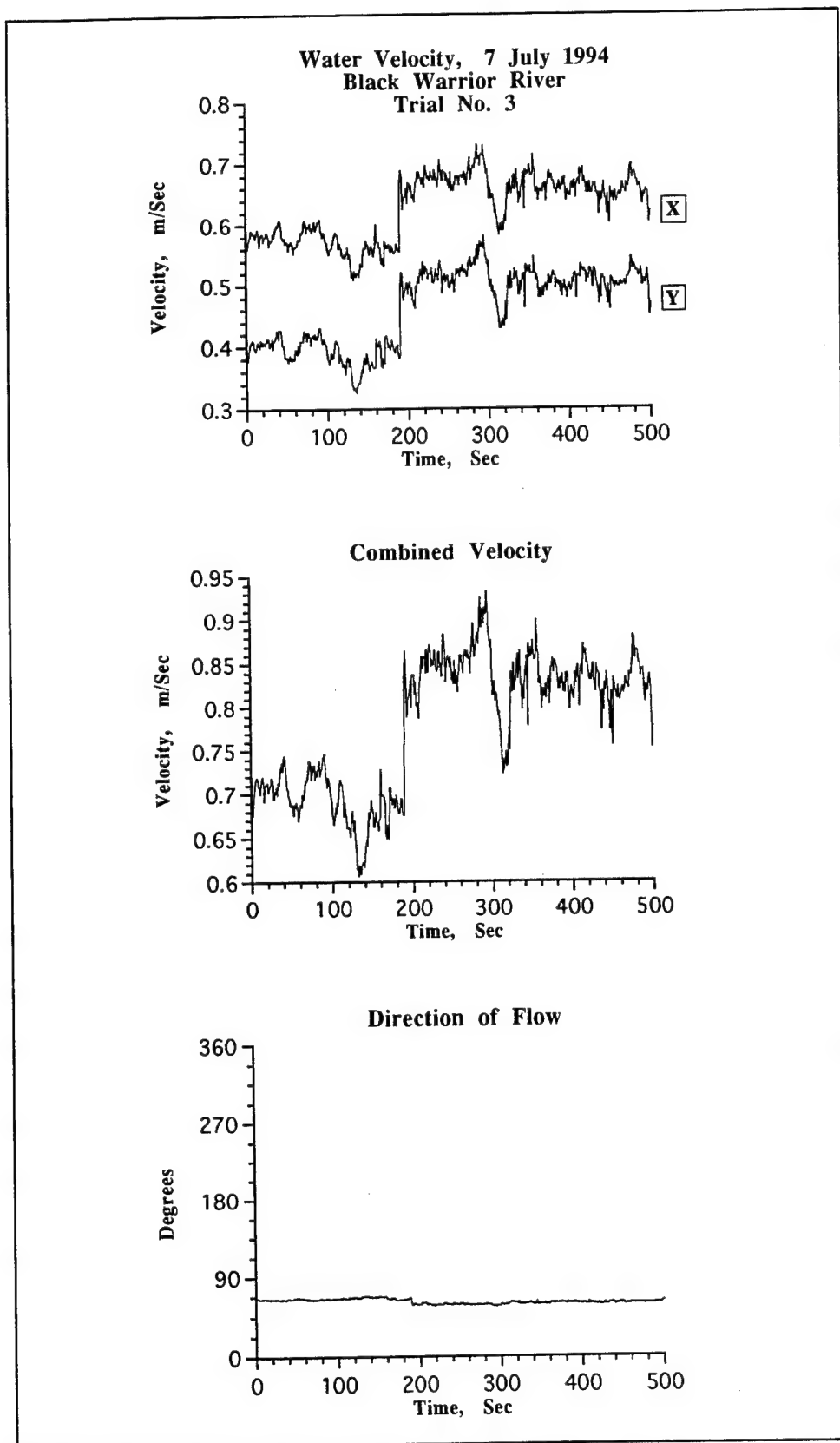


Figure B4. Single axis velocity, net velocity, and direction of flow for Trial No. 3, RM 326.9 LDB, 7 July 1994, 16:08-16:16

Appendix C
Reburial Rates of *Potamilus*
***inflatus*, Black Warrior and**
Tombigbee Rivers, July 1994

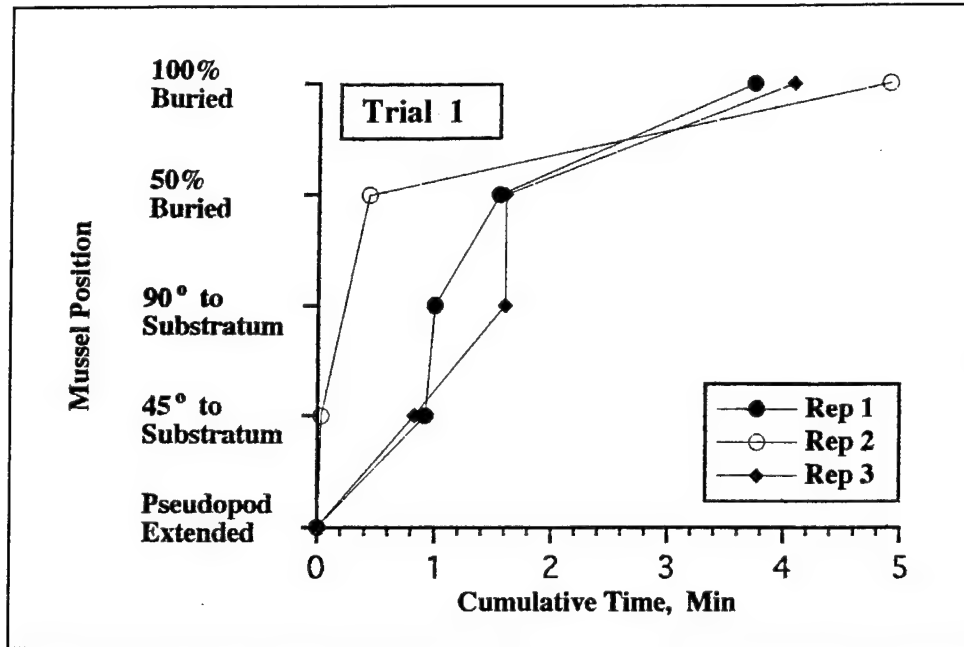


Figure C1. Reburial rates for *P. inflatus*, 31.5 mm total shell length. During Replicate 2, mussel completely buried at an angle of 67.5° to substratum, never becoming vertical

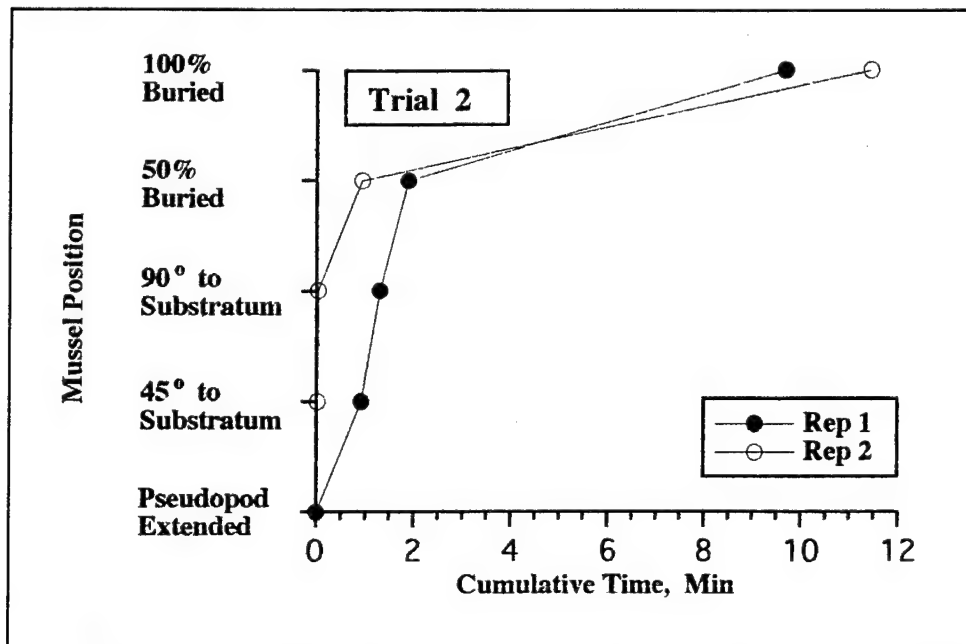


Figure C2. Reburial rates for *P. inflatus*, 35.6 mm total shell length

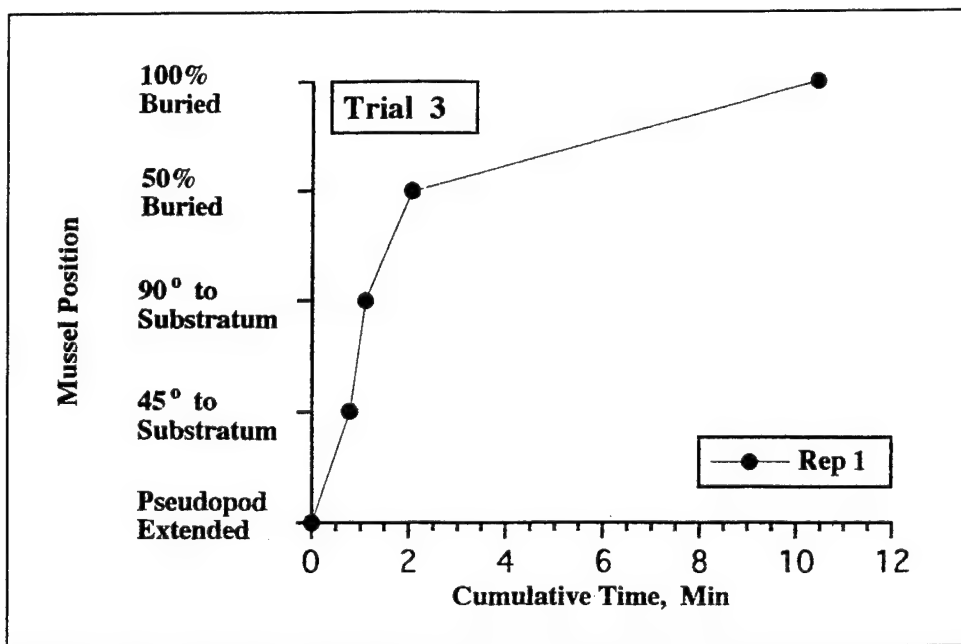


Figure C3. Reburial rate for *P. inflatus*, 35.9 mm total shell length

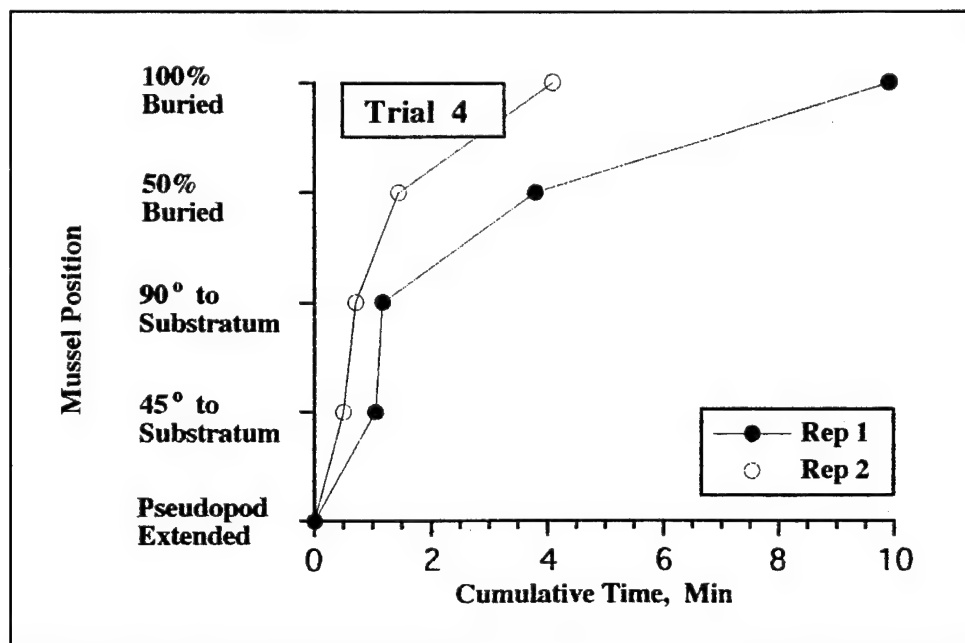


Figure C4. Reburial rates for *P. inflatus*, 36.2 mm total shell length. Between minutes 2 and 4 of Replicate 1, mussel moved approximately 4 in. toward center of channel

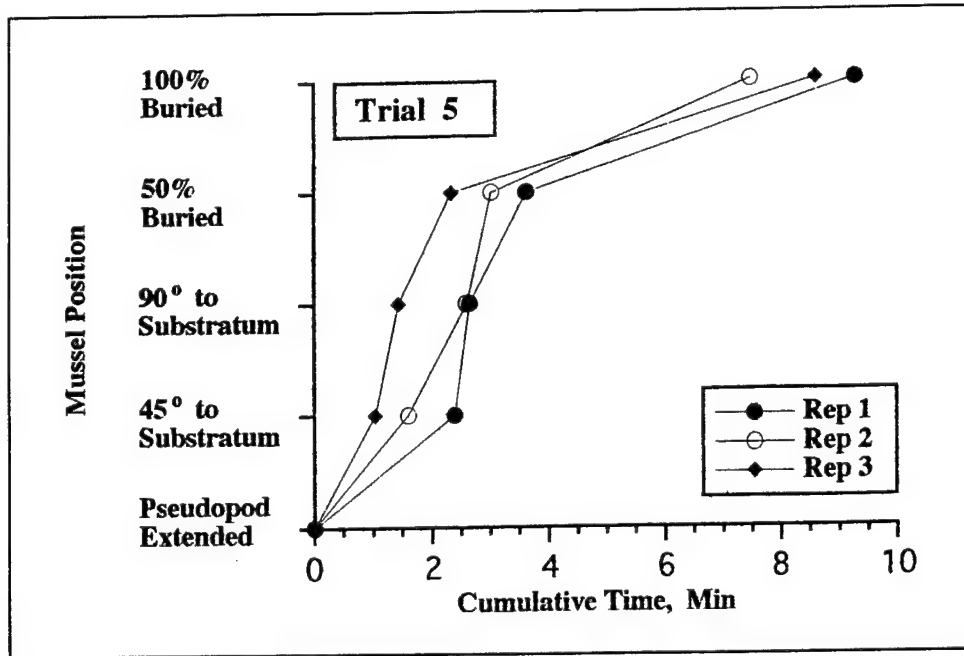


Figure C5. Reburial rates for *P. inflatus*, 37.1 mm total shell length

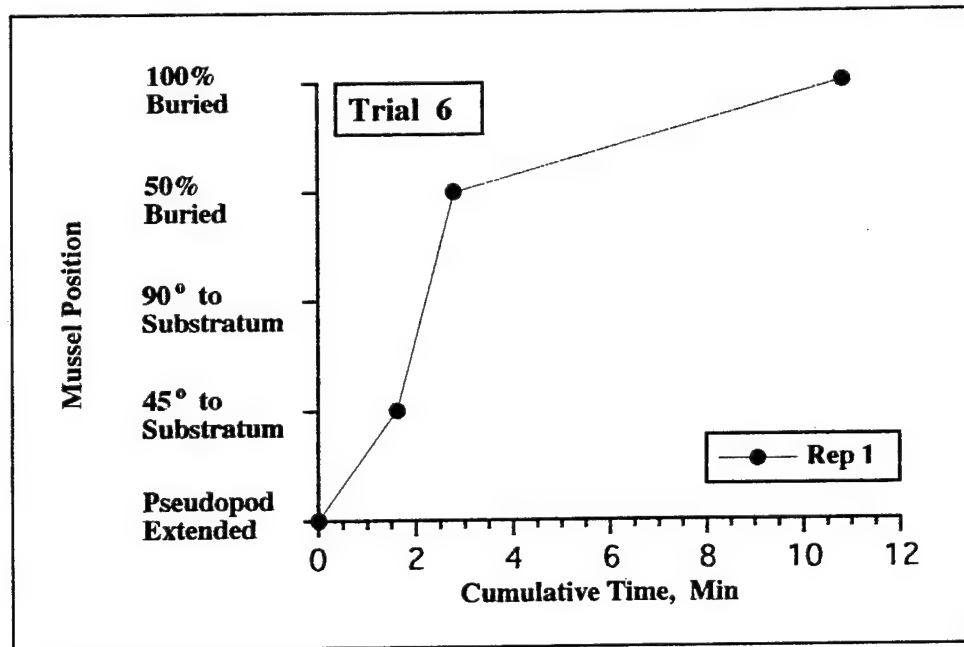


Figure C6. Reburial rate for *P. inflatus*, 38.3 mm total shell length. During Replicate 1, mussel completely buried at an angle of 67.5 deg to substratum, never becoming vertical

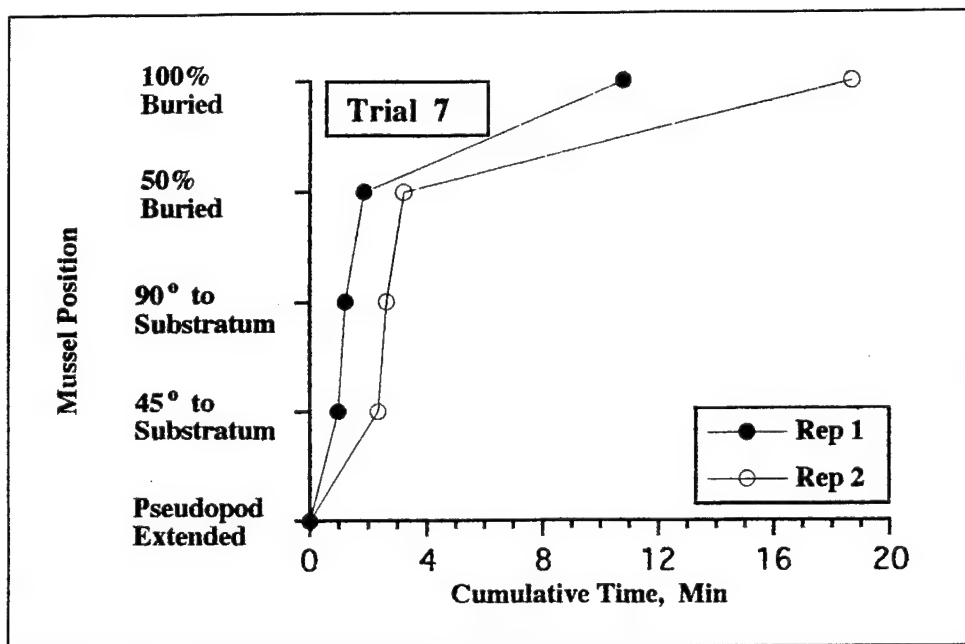


Figure C7. Reburial rates for *P. inflatus*, 39.0 mm total shell length

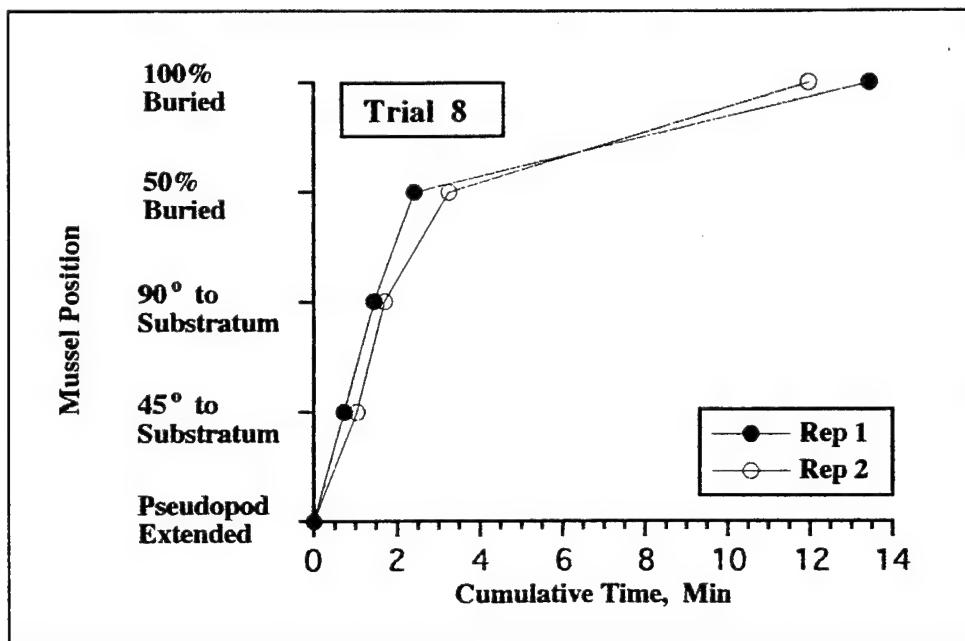


Figure C8. Reburial rates for *P. inflatus*, 56.1 mm total shell length

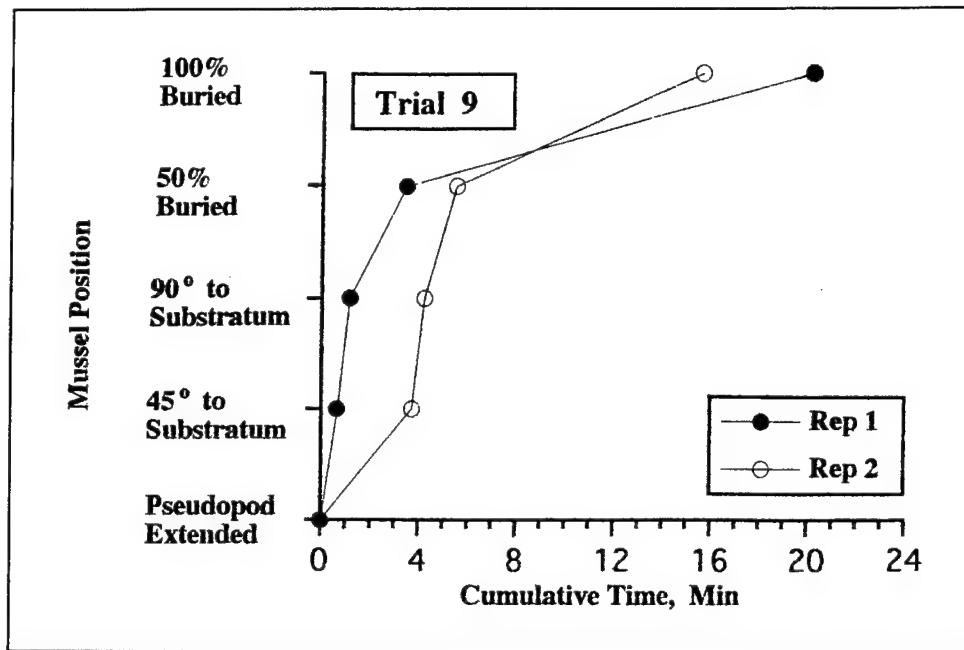


Figure C9. Reburial rates for *P. inflatus*, 68.7 mm total shell length

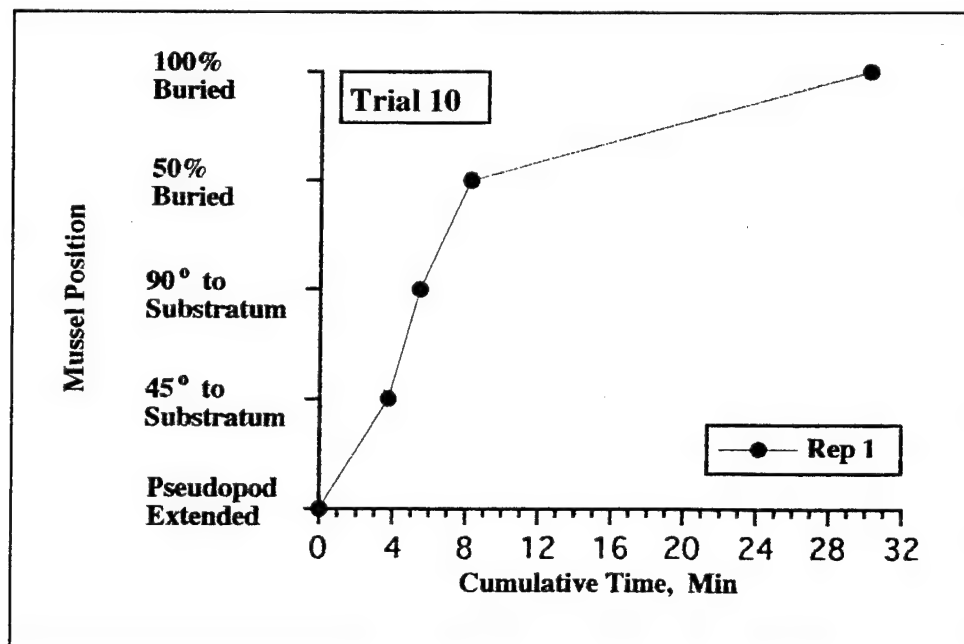


Figure C10. Reburial rates for *P. inflatus*, 77.5 mm total shell length

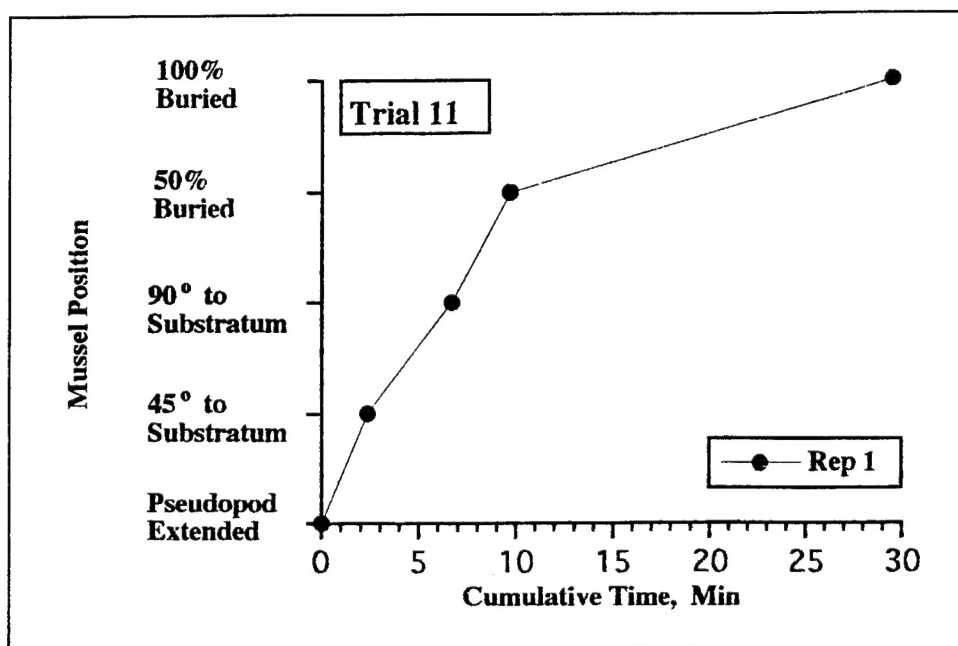


Figure C11. Reburial rates for *P. inflatus*, 83.0 mm total shell length

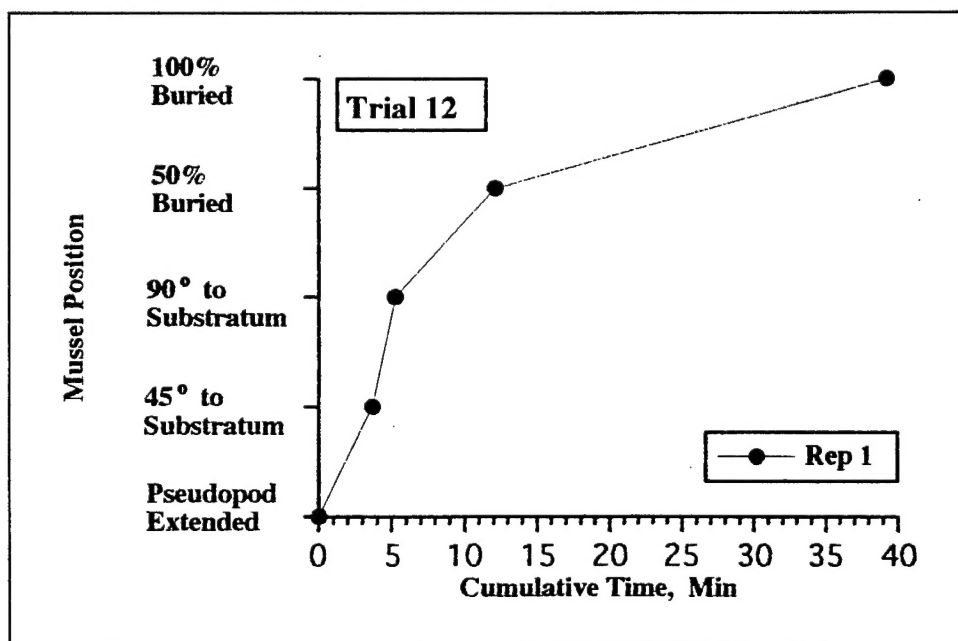


Figure C12. Reburial rates for *P. inflatus*, 114.5 mm total shell length

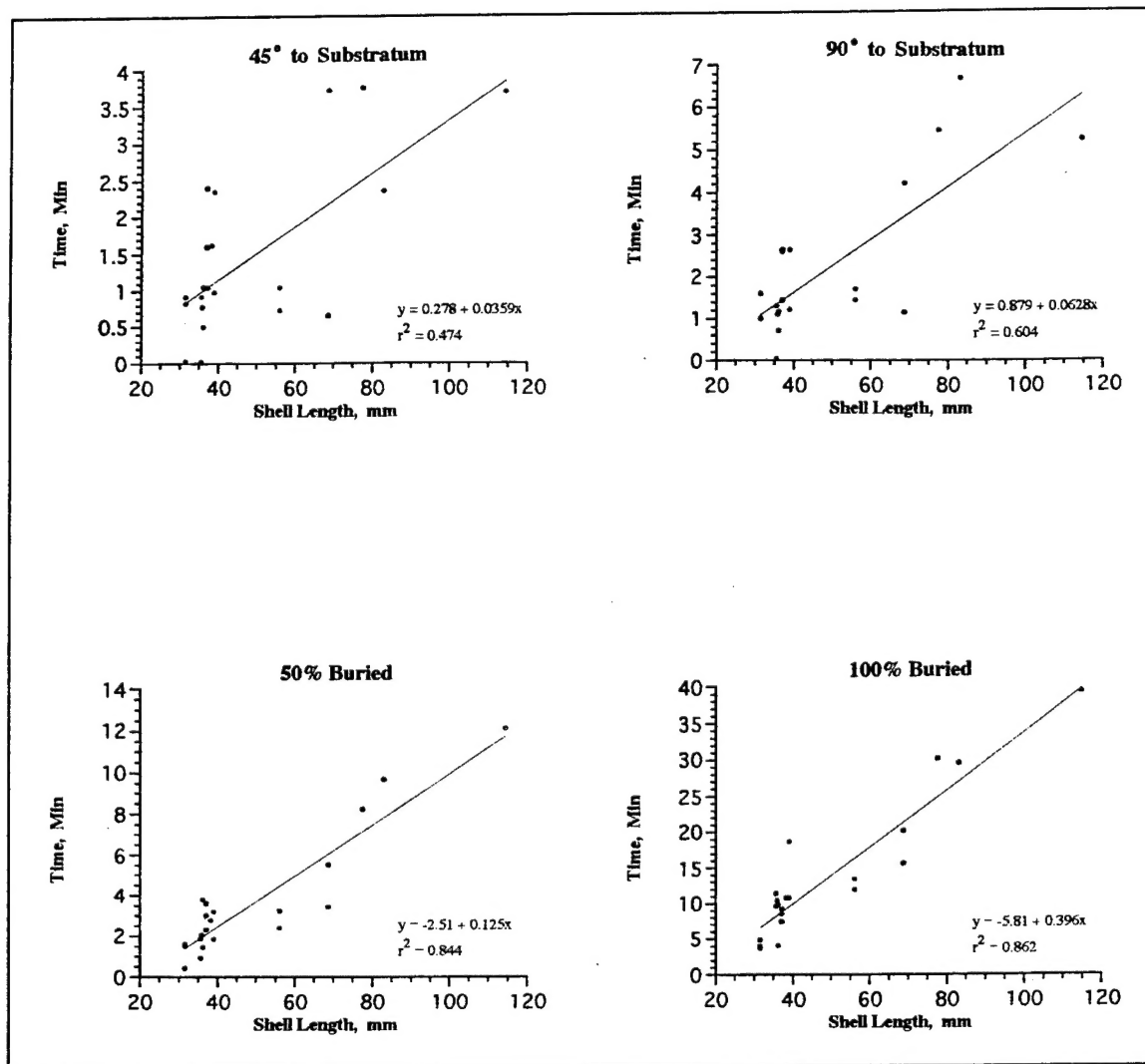


Figure C13. Comparison of reburial rates for *P. inflatus* with total shell lengths ranging from 31.5 to 114.5 mm

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13. ABSTRACT (Maximum 200 words) <p>The biology and ecology of the inflated heelsplitter mussel (<i>Potamilus inflatus</i>), listed as threatened, was studied at dredged material disposal areas, adjacent areas unaffected by disposal, and two stable gravel bars on the Black Warrior and Tombigbee (BWT) rivers in July 1994. Objectives were to (a) determine density, size, and age of <i>P. inflatus</i> in silt/sand substratum at areas affected and unaffected by disposal of dredged material; (b) determine density, size, and age of <i>P. inflatus</i> at high-quality, stable gravel bars never affected by dredging; (c) collect data on water depth, velocity, and substratum type where <i>P. inflatus</i> was found; and (d) examine the ability of <i>P. inflatus</i> to rebury after being dislodged from the substratum and to extricate itself after being buried in sand.</p> <p>Mean density (individuals/square meter, \pm standard error of the mean) of <i>P. inflatus</i> at a gravel bar immediately downriver of Demopolis Lock and Dam ($0.3, \pm 0.17$) was substantially greater than density in fine-grained sediments unaffected by dredged material disposal ($0.0097, \pm 0.0029$) or in disposal areas used in 1993 ($0.005, \pm 0.0015$). Recently used disposal areas supported large and small mussels, indicating that this species populates these areas through natural recruitment and dispersal by high water.</p> <p style="text-align: right;">(Continued)</p>				
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13. (Concluded).

Depending on their size, *P. inflatus* required between 5 and 90 min to completely rebury after being dislodged from the substratum. However, when covered by 10 cm of sand, mussels were unable to extricate themselves. Although dredging in the BWT rivers can adversely affect the inflated heelsplitter mussel, this species is able to rapidly reinvade recently disturbed disposal areas.